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HERBACEOUS VEGETATION CONTROL WITH HERBICIDES DURING CONIFER SEEDLING ESTABLISHMENT FOR REFORESTATION

by

© D.G. Blackmore

A THESIS
SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH
IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE
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IN

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DEPARTMENT OF PLANT SCIENCE

EDMONTON, ALBERTA
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THE UNIVERSITY OF ALBERTA

FACULTY OF GRADUATE STUDIES AND RESEARCH

The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research, for acceptance, a thesis entitled

Herbaceous Vegetation Control with Herbicides
During Conifer Seedling Establishment for Reforestation

submitted by D.G. Blackmore in partial fulfilment of the requirements for the degree of Master of Science in Plant Science.

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Date April 14, 1978

ABSTRACT

Foliar sprays with glyphosate at 4.5 kg/ha in 1.2 m wide strips and 28 and 56 cm diameter spots, shortly before implanting yearling white spruce (Picea glauca (Moench) Voss) and lodgepole pine (Pinus contorta Loudon var. latifolia Engelm.) seedlings in 3 forest clearing sites, provided nearly complete control of perennial grasses within 2 weeks after spring treatment. By the fall of the same year there was 20-50% reinvasion at different locations increasing to 35-75% by the fall of the next year. Both sizes of spots were reinvaded more than were the strips. Vegetation control in scalped spots 9.3 dm^2 remained, in general, equal to or better than in glyphosate treated strips.

Somewhat less vegetation reinvasion occurred in the following year after late summer applications of glyphosate at 4.5 kg/ha than occurred after 4.5 kg/ha applied in the spring. Summer treatments with glyphosate from 2.2 to 5.6 kg/ha were only slightly more effective than a 1.1 kg/ha dosage.

Final data recorded 14 months after planting yearling spruce seedlings in plots sprayed with 4.5 kg/ha of glyphosate the day before planting showed injury at one site and no benefit at the others. Both spruce and pine seedlings were sensitive to direct spraying. Pine seedlings planted within 1 day or immediately after treatment with from 1.1 to 6.7 kg/ha of glyphosate were in most cases seriously damaged, evidently by unexpected short-term soil activity of glyphosate and less likely by possible transfer of glyphosate from grass leaves to pine leaves. Seedlings planted 6 days or 10 months after spraying were not injured by glyphosate.

Fourteen months after planting spruce and pine seedlings into fertilized and unfertilized scalp treatments there tended to be improvement in seedling condition, height and weight compared with other treatments. The best height and weight increases of spruce and pine seedlings occurred in fertilized scalps where height increases at 3 sites averaged 30% more than the controls. There was no improvement in height and weight of fertilized spruce or pine seedlings in glyphosate treatments compared with unfertilized spruce and pine in similar plots.

Fertilization of spruce seedlings in controls without scalping or herbicide treatment tended to result in some growth increases. Pine appeared to respond favorably in the same growing season and the next year after fertilizer treatments while spruce apparently increased only in the next year after treatment.

Willow planted in 1.2 m strips, 1 day after spring spraying with 4.5 kg/ha of glyphosate increased in weight substantially more than willow in the control or 28 cm spot treatments finally assessed after 14 months.

Satisfactory vegetation control followed applications of karbutilate, Velpar, atrazine and a mixture of simazine, atrazine and Velpar (2.5: 2.5: 2). However, poor survival and/or growth occurred with spruce and pine seedlings planted directly into plots sprayed with these herbicides on the previous day. Direct treatment of conifer seedlings with Velpar, fluridone and the herbicide mixture resulted either in low survival or poor condition of conifer seedlings. Conifer seedlings planted into scalps in strips in which the herbicide mixture was applied immediately prior to scalping had superior growth compared with all other soil treatments when observed only 3.7 months after treatment . This later promising technique must await later observations before its success can be appraised definitely.

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This thesis is dedicated to my wife, Marlynne, who assisted at various stages of the experimental work and whose encouragement throughout the project was greatly appreciated.

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INTRODUCTION

Forests occupy two-thirds of the total land area of Canada's 10 provinces but a major part of this area has extremely wide variations in its capability to grow timber (Bickerstaff 1963). In Alberta, there is a total of approximately 12 million hectares of coniferous and mixed wood forest (Alberta Forest Service 1968). During the period from 1966 to 1976, the area harvested in Alberta amounted to about 14.7 thousand hectares annually (Alberta Forest Service 1977). This annual harvest, which includes primarily white spruce (*Picea glauca* (Moench) Voss) and lodgepole pine (*Pinus contorta* Loudon var. *latifolia* Engelm.), represents approximately 0.12 percent of the total forest land in Alberta. In order to insure that logged areas are adequately restocked, the Timber Management Regulations of the Province of Alberta require that every cut area must be adequately reforested with a minimum of 320 evenly distributed, acceptable trees per 0.4 hectares (1 acre) (Alberta Lands and Forests 1973).

Available information suggests that not all harvested areas have been satisfactorily restocked in accordance with the Timber Management Regulation requirements. Reforestation of pine (surveyed ten years after establishment) and spruce (surveyed seven years after establishment) have been only 80 and 65 percent successful, respectively, in fulfilling the requirements of the regulations (Hellum 1977). Hellum (1978) estimates that on five to fifteen percent of the total logged area, there are difficulties encountered in establishment and survival of coniferous seedlings because of wet conditions resulting from a rise in the water table as a result of removal of the forest trees. By removing the trees, the transpirational water loss from the forest is eliminated and more water is retained in the soil. High soil moisture levels plus an increase in soil temperature resulting from increased exposure to sunlight result in the abundant growth of grasses such as marsh reed grass (Calamagrostis canadensis (Michx.) Beauv.). Conditions of poorly aerated soils, periodic flooding and competition from dominating grass often result in poor survival of conifers.

There are also appreciable amounts of cut over land that do not have a high water table but which, nevertheless, have become infested with perennial grasses and other vegetation preventing satisfactory conifer re-establishment. Adjacent, uncut parent trees intended to scatter new conifer seed to the harvested areas may, because of poor 'seed years', fail to produce another crop of seed before the cleared area has become densely covered with weedy vegetation. The problem is worse with spruce than pine since pine has a 'carry over' of seed in its serotinous cones on the trees and in the scatter slash. In addition, pine competes better because it grows more rapidly than spruce in its seedling years. Rodents and unfavorable weather conditions also contribute to the poor success of seedling regeneration. Neglecting to scarify the site soon enough after the harvest or omitting this operation altogether can also result in poor natural forest regeneration. Scarification is the most common method of site preparation used in Alberta for temporarily controlling vegetation that competes with conifer seedlings. In this operation the soil surface is disturbed, usually by crawler tractors with various blades and attachments. The objective is to expose mineral soil or provide a mixture of mineral soil and humus on 30 to 70 percent of the site. (Stiell 1976).

Hand scalping for preparation of individual seedling spots is another site preparation method practised in Alberta. This procedure involves the removal of the competing vegetation and organic matter with a mattock to expose mineral soil in a spot approximately 9.29 dm^2 (1 ft^2). Hand scalping is usually practised in areas where machine scalping is not feasible because of rough terrain, steep slopes or excessive slash. Herbicidal control of perennial grasses and forbs has not yet been investigated fully as a potential practical procedure in forest regeneration programs in Alberta.

In view of the possible value of herbicides for herbaceous vegetation control in reforestation work noted in the literature review and also as a result of the expressed interest of foresters of North Western Pulp and Power Limited, Hinton, Alberta and of Alberta Energy and Natural Resources, the present investigation was begun in 1976.

Experiments have been mainly concerned with the extent and duration of efficacy of certain foliage treatments and soil applied herbicides and with associated techniques used immediately before planting white spruce and lodgepole pine for control of weedy perennial herbaceous vegetation. The main objective has been to attempt to control the undesirable vegetation without injuring the conifer seedlings and to improve their survival and growth in harvested areas intended for reforestation. The major emphasis has been placed on trials with glyphosate, a relatively new foliage-applied herbicide (Monsanto 1973) that has so far been used in only limited exploratory tests with seedling conifer implants. Acceptable treatments that could protect the slow growing conifer seedlings from excessive competition by associated vegetation for a period of at least two years would be beneficial for improved forest management.

In order to broaden the scope of the project beyond the forest industry, two species of deciduous trees: caragana (Caragana arborescens Lam.) and acute leaf willow (Salix acutifolia) were included. Some examples of the potential uses of implanted deciduous species follow.

Powerline and pipeline companies with rights-of-way in wooded areas must implement costly herbicidal or mechanical measures to prevent tall, fast growing tree species such as trembling aspen (Populus tremuloides Michx.) from interfering with operation or maintenance of the right-of-way. Some rights-of-way managers have expressed, to the author, their views of the desirability of eliminating or reducing costly woody vegetation control operations by establishment of a low growing, stable woody plant population on part or all of the right-of-way.

Industrial development often results in removal of the natural vegetation, therefore it is often desirable to establish fast growing woody species for general revegetation and slope stabilization. In addition, the planting of shelterbelts directly into sod without prior cultivation, particularly in areas subject to erosion, may be accomplished more successfully by controlling the competing vegetation with herbicides.

As with the conifers, the objective in including deciduous species in this investigation was to evaluate the effect of herbicide treatments on weedy vegetation and on survival and growth of the two species.

In addition to the field studies, some supplementary, relevant greenhouse trials were undertaken with lodgepole pine.

LITERATURE REVIEW

Presence of Herbaceous Vegetation in Forest Clearings

The early establishment of grasses and forbs as a result of ecological succession after clear cutting forested land can obviously have some effect on subsequent reforestation progress. Rapid changes in abundance of herbaceous plant species commonly occur following clear cutting of lodgepole pine in the lower foothills of Alberta (Corns and La Roi 1976). In their study, common invaders of recently clear-cut areas were fireweed (*Epilobium angustifolium* L.), marsh reed grass (*Calamagrostis canadensis* (Michx.) Beauv.) and hairy wild rye (*Elymus innovatus* Beal.). These species increased dramatically after clear cutting as compared with their much lesser abundance in adjacent mature pine stands.

In an experiment in the foothills of Alberta, conducted to test herbicides for vegetation control on a clear-cut white spruce area, Corns and Gupta (1971) noted that "Much of this cleared area is now heavily covered with grasses, mainly hairy wild rye". In observing early pine forest succession 10 to 20 years after fire in the eastern slopes of the Rockies, Cormack (1953) noted that the open sites were characterized by "a great mixture of grasses and native herbs". "Smooth wild rye grass" is named as one of the most frequently occurring plants.

In the introduction, reference has already been made to some factors involved in establishment of grasses on cut-over forest land. Moreover, the literature cited above supports the idea of rapid invasion of grasses and forbs following forest clearing. Therefore, the resultant presence of dense stands of grasses and forbs in forest clearings during the initial stages of ecological succession is not unusual and competition for site resources with planted and natural conifer seedlings can be expected. Such competition might prevent the achievement of satisfactory forest regeneration within an acceptable period of time.

Competition by Grasses and Forbs

The literature provides numerous statements of the competition that exists between grasses and conifer seedlings for site resources. Waldron (1966) indicated that vegetative competition, primarily as a result of tall dense marsh reed grass, was an important factor in seedling mortality in an experiment in the Riding Mountain Forest Experimental Area, Manitoba. Mortality of natural white spruce as a result of vegetative competition was 18 and 6 percent on undisturbed and disced sites respectively.

In forest plantations, there are two main sources of competition: grasses and forbs, and woody plants (Sutton 1969). Sutton indicated that the main resources for which plants compete are light, moisture and nutrients with the importance of the latter often being underestimated.

The literature supports the assumption that competition is most severe during the first two growth seasons of planted conifers and deciduous tree species. White (1967) suggested that competition during this period can have a strong negative effect on survival and tree form. If a tree lapses into a condition of "check" because of weed competition in the first two years then that tree's ability to compete with weeds after two years is impaired and, at best, the establishment period is lengthened (Sutton 1969).

White (1975) believed that weed control in coniferous plantations during the establishment stage is one of the management factors that has greatest potential in increasing biomass production and tree quality. He also noted that grasses and broadleaved plants were the major competing vegetation during the initial years of production. Newton (1974) pointed out that "New forest plantings in areas occupied by grasses and forbs often need weed control to aid in their establishment". The length of time required to establish conifers is "almost entirely dependent on the habits of competing vegetation" (Anon 1968). In Christmas tree plantations, it is reported that weeds may reduce survival rates, stunt growth, result in poor foliage cover and prolong the rotation (Anon 1968).

It is, therefore, generally clear from the literature that grassy weeds and forbs often dominate tree species resulting in their reduced growth and vigor and generally prolonging the crop rotation. The evidence is that control of invading grasses and forbs in coniferous plantations can be of paramount importance during the first two years of the establishment stage.

Cultural Control

Cultural control methods were used in the first attempts to control weeds in coniferous plantations. The traditional method used in the United States and eastern Canada in intensive reforestation projects was the plowed furrow into which the trees were planted (Stiell 1976). Furrows, however, resulted in the area being difficult to travel with machines (Stiell 1976) and also caused a potential erosion problem (White 1975).

Another cultural vegetation control method commonly practised in reforestation projects is scalping, already explained in the introduction. Seedlings are planted in individual scalps (Stiell 1976). Newton (1974) pointed out that the scalp is "limited in its effectiveness by reinvasion of weeds and required substantial extra cost in labor". White (1975) noted that under central United States conditions, scalping and furrows were only used during the "preherbicide era" and that now these cultural measures are almost entirely unnecessary. This statement seems subject to reservations with regard to conditions in Alberta.

At present, methods of site preparation in clear cuts in Alberta are reported to be scarification of various types including crawler tractors with angled, straight and toothed blades, vee blades and brush rakes (Hellum 1977). Hellum (1977) quoted the Alberta government's Scarification in Reforestation Manual as indicating that the brush rake is the most useful scarification machine for use on spruce sites. The main purpose of scarification is to expose mineral soil or provide a mixture of mineral soil and humus on 30 to 70 percent of the site into which conifer seed is sown or into which conifer seedlings are planted. In addition, scarification often makes the site more accessible to work crews and machines and also improves the drainage (Stiell 1976). Top growth of herbaceous vegetation growing at the time of scarification will be controlled but rapid reinvasion often occurs. Hellum (1977) noted that winter scarification, which was as common as summer and fall scarification by 1975 in Alberta, leads to "heavy vegetation reinvasion".

Mechanical and hand site preparation methods commonly practised in forest clearings in preparation for planting conifer seeds or seedlings have a number of advantages, as mentioned above, which make the practise valuable and necessary. In controlling competing vegetation, however, the site preparation methods mentioned above appear less than adequate, therefore new methods of supplementing mechanical and hand site preparation should be designed to provide at least two years freedom from competition by grasses and forbs. In the establishment of coniferous plantations in the United States and eastern Canada, cultural control of weedy vegetation appears to be regarded with lessening favor and herbicidal methods are being investigated as a practical method of providing freedom from competition in the establishment years.

Herbicidal Control

Hovind (1959) in Wisconsin, conducted one of the earlier experiments where survival data and indications of growth and thriftiness of a coniferous species were taken after various herbicide treatments. Two year old red pine (Pinus resinosa Ait.) seedlings were planted in a moderately dense stand of quackgrass with treatments including simazine, dalapon, amitrol, various combinations of these three herbicides, a plowed furrow and a control. The spraying and planting operation was done simultaneously without spraying the trees. At the end of the first year of the experiment, grass control in the herbicide treatments was nearly equivalent to or better than in the plowed furrow. At the end of the second year, the mean survival of red pine for the two rates of simazine (1.7 (1.5) and 3.3 (3) kg/ha (lb/A)) was 38 percent whereas survival of red pine in the plowed furrow and control treatments were 17 and 0 percent respectively. The highest survival of red pine occurred in the simazine-dalapon plots where 59 percent was achieved. Hovind (1959) described the red pine seedlings in the simazine at 3.3 kg/ha plots (3 lb/A) and in the simazine-dalapon mixture plots as being "thrifty" while the red pine in the furrow were declared "moderately unthrifty". Hovind indicated that since the experiment was conducted during an abnormally dry period, the herbicide treatments resulted in conservation of moisture for the use of the conifers, thus increasing their survival. He further stated that it is desirable to include both a fast-acting herbicide and a long-lasting herbicide for best results.

Hovind's experiment was conducted under Wisconsin conditions using red pine, therefore the results may not be applicable to Alberta where red pine is not grown. The observations were based on visual assessments of condition or "thriftiness" for which no predetermined scale is reported. These assessments are, therefore, very subjective in nature and open to possible misinterpretation. Percent survival data, although generally indicating poor survival over the entire experiment, appear to be objective and therefore can be accepted.

Von Althen (1972) reported an eight year afforestation study in Ontario which provided survival and height data for 4 year old (2+2) white pine (Pinus strobus L.) and white spruce in addition to six species of deciduous trees. The treatments included plowing and disking, scalping, simazine alone, simazine plus fertilizer and a control. Herbicide and fertilizer treatments were applied in granular formulation "shortly" after planting. Eight years following initiation of the experiment, white pine had grown an average of 0.91 (3.0), 1.46 (4.8) and 1.25 (4.1) m (ft) in the control, simazine (rate not given) and simazine plus fertilizer (N-168 (150), P-89.6 (80) and K-89.6 (80) kg/ha (lb/A)) plots respectively. White spruce had grown an average of 1.01 (3.3), 1.34 (4.4) and 1.58 (5.2) m (ft) in the same plots reported above for white pine. Von Althen (1972) indicated that white pine achieved satisfactory survival only on plowed and disked plots that were also treated with simazine. In the scalped plots, the chemical treatments did not improve the growth of either of the conifers. Data supporting either of these claims are not provided. This report however, does provide data tending to indicate increased growth of conifers as a result of herbicide treatments although the differences are not shown to be statistically significant.

In a summary of his own experiments conducted in northeastern United States during 1966 and 1967, White (1967) presented results indicating that atrazine and simazine successfully prevented mortality of white spruce transplanted into heavy quackgrass sod. In an experiment concluded in 1966 in which atrazine was applied at dosages of 2.2 (2.0) kg/ha (lb/A) before planting, "partial control" of weeds was observed and no mortality of white spruce transplants occurred. In the control plots, mortality of white spruce transplants was 30 percent. Similar results were obtained using simazine applied once before planting (in the same year as planting) and again one year later at 4.5 (4.0) kg/ha (lb/A).

In a similar experiment concluded in 1967, White (1967) applied simazine at 4.5 (4.0) and 9.0 (8.0) kg/ha (lb/A) and simazine plus atrazine both at 2.2 (2.0) kg/ha (lb/A) which again resulted in no white spruce mortality. White spruce transplanted into control plots suffered 10 percent mortality. Applications at the 9.0 (8.0) kg/ha (lb/A) rate of simazine and the 2.2 (2.0) kg/ha (lb/A) rates of simazine plus atrazine resulted in "partial control" only.

Data presented in White's (1967) report were obtained from five replications although statistical analysis to determine if there were significant differences between treatments was not included. No indication of the number of white spruce transplants per replicate was given. The weed control rating system appears subjective in nature and no explanation or definition of the terms used is given, e.g., "commerically practical" and "partial control".

Sutton (1975) found strong survival, growth and nutritional responses of 3 year old (1+2) white spruce transplants following treatments with a paraquat-simazine herbicide mixture applied the fall before spring planting. Working in eastern Ontario in an area covered by a dense growth of grass dominated by bentgrass (Agrostis stolonifera L.), quackgrass (Agropyron repens (L.) Beauv.), timothy (Phleum pratense L.) and perennial ryegrass (Lolium perenne L.), Sutton found the survival of white spruce after three years to be 22 and 94 percent for untreated and treated (paraquat-simazine) plots respectively. The growth of white spruce after three years was significantly higher in the treated plots (mean of 24.8 cm per tree) compared to the untreated plots (mean of 18.0 cm per tree). The foliage concentration of nitrogen after the first two years of the experiment was numerically higher (although not significantly) in white spruce grown in treated plots (2.29 ppm N) compared to untreated plots (1.32 ppm N). The nutrients P, Ca and Mg were all found to be in higher concentration in the foliage of white spruce in the treated plots in the first year. During the first growing season, soil moisture in each of the plots was determined at regular intervals on four separate dates. On two of the four moisture testing dates, moisture levels were significantly higher in the treated plots compared with the untreated plots.

Important advantages of weed control with herbicides were pointed out and supported with data in Sutton's (1975) paper. The control of grasses resulted in increased availability of both moisture and nutrients. In an earlier paper, Sutton (1969) indicated that a herbicide treatment is similar to a fertilization treatment. Herbicides in effect divert part of the resources of the site from weed species into crop trees, often resulting in significant increases in height growth in the following year. This study (Sutton 1975) bears out his earlier view (1969) that herbicide treatments improve soil fertility. In addition, this later research shows some moisture conservation benefits from appropriate herbicide treatments.

In a report on herbaceous weed control in potential coniferous plantations with uncultivated sod conditions in the northeastern region of the United States and eastern Canada, White (1975) listed a number of herbicides and rates of application which have been reported to provide successful weed control. Preplant herbicide treatments in 0.61 (2.0) to 0.76 (2.5) m (ft) wide strips in abandoned farmland (heavy sod) are suggested to include simazine applied at 2.2 (2.0) - 6.7 (6.0) kg/ha (lb/A), simazine plus atrazine both applied at 2.2 (2.0) kg/ha (lb/A) and simazine plus amitrole-T both applied at 2.2 (2.0) kg/ha (lb/A). Mowing before treatment with the above mentioned herbicides and planting coniferous species 7 to 10 days after treatment is recommended. White (1975) also lists glyphosate applied at 1.7 (1.5) kg/ha (lb/A) in combination with simazine applied at 3.3 (3.0) kg/ha (lb/A) as being reported to provide successful control of quackgrass in potential coniferous plantations. However, White's paper failed to list coniferous tree species or weed species involved (except quackgrass control by glyphosate) with the various herbicide treatments. White also indicated that the herbicides, herbicide combinations and rates of application listed are not recommendations for general weed control in coniferous plantations. He suggested that the registered uses, as stated on the herbicide container label, must be followed. Herbicide usage in coniferous plantations therefore appears not to be an established management practise as late as 1975 in the northeastern region of the United States and eastern Canada.

The only reported experimental work involving herbicides and herbaceous vegetation control in coniferous plantations in Alberta, that the author is aware of, is that of Corns, Gupta and Cole (1971, 1972 and 1973). All experiments in this continuing series were conducted near Hinton, Alberta in a clear-cut forested area heavily covered with grasses (mainly hairy wild rye). The objectives of these experiments were to determine the value of herbicides in controlling grasses and forbs and for releasing established seedling conifers or aiding in preparation of better tree seed beds. Planted white spruce and lodgepole pine seedlings were also included in these experiments.

The first experiment (Corns and Gupta 1971) included simazine, karbutilate, bromacil and atrazine at dosages ranging from 6.7 (6.0) to 20.5 (18.0) kg/ha (lb/A) applied to perennial grasses and other mixed vegetation including some regenerating white spruce ranging from 4 to 7 years old. Results a year after treatments supported the general conclusion that dosages of these herbicides sufficient for satisfactory general vegetation control were toxic to the regenerating spruce trees.

Year old spruce and pine seedlings were planted in 6.7 (6.0) and 20.5 (18.) kg/ha (lb/A) plots of bromacil, karbutilate, atrazine and simazine a year after application of these herbicide treatments (Corns and Cole 1972). Both pine and spruce implants appeared healthy at the end of that same growing season in the plots treated with 6.7 (6.0) kg/ha (lb/A) of karbutilate, atrazine and simazine. For the higher dosages where there had been good grass control, pine seedlings appeared healthy in all plots except bromacil. Spruce seedlings seemed less tolerant than pine and appeared unaffected only in the atrazine plot.

On the basis of these results, a supplementary experiment was set out in the same area in the following year (Corns and Cole 1973). It included atrazine and glyphosate sprayed on native grass and white spruce. Also, there were one year old seedlings of white spruce and lodgepole pine planted before or the day after spraying with dosages of 2.2 (2.0) and 3.3 (3.0) kg/ha (lb/A) of glyphosate and 4.5 (4.0) and 5.6 (5.0) kg/ha (lb/A) of atrazine. Two growing seasons after the start of this experiment mortality of white spruce planted the day after spraying was 24 and 36 percent for 2.2 and 3.3 kg/ha of glyphosate compared with the check which had 16 percent mortality. In the same time period, mortality of lodgepole pine planted the day after spraying was 12 and 48 percent for 2.2 and 3.3 kg/ha of glyphosate compared with 16 percent for the check. The mortality of white spruce planted after atrazine spraying was 80 and 92 percent for 4.4 (4.0) and 5.6 (5.0) kg/ha (lb/A) respectively, while lodgepole pine mortality was 40 and 32 percent for the same application rates. Apparently glyphosate at 2.2 kg/ha before planting had no pronounced undesirable effect on either species within 15 months after treatment. Grass control was "very good" with glyphosate in the first year and persisted longer for atrazine in the second year. Planted lodgepole pine were more tolerant of atrazine than planted white spruce. Over-the-top sprays with both herbicides were toxic to both species.

From the evidence presented, it is apparent that newly cleared forest areas often are invaded by grasses and forbs which provide competition to newly planted coniferous species. Under Alberta conditions, cultural control through scarification and scalping are the only methods of vegetation control practised before planting. Herbicides have been used successfully for vegetation control in several experiments in various parts of the United States and eastern Canada. However, there appears to be little evidence that such use of herbicides has been adopted as a general forest practise or that the results noted in the reviewed literature have direct applicability to the kinds of perennial weeds, species and relative age of trees and other environmental factors involved in the challenging problem in Alberta.

In summary of the kinds of herbicides used in the work reported above, experiments on chemical control of undesirable herbaceous forest vegetation have involved "short term" soil sterilants such as dalapon which may be used as a foliage and as a soil treatment and herbicides with longer term residual effects in the soil, e.g., atrazine and simazine. In addition foliar-applied herbicides like paraquat have been used for their top-killing action with no residual effect in the soil and no ability to translocate and kill perennial root systems. Glyphosate, is also effective against a wide variety of plant species and can translocate effectively to the root system of many perennial plants. It does not have the extent of residual effects of the soil treatments mentioned above. Consequently, glyphosate has been used successfully for control of perennial grasses, e.g., quackgrass (Agropyron repens (L.) Beauv.) combined with successful production of grain crops seeded immediately after cultivation or as soon as the foliage of the grass was nearly all dead several days after the glyphosate was applied (Valgardson and Corns 1974). For this reason, glyphosate as mentioned earlier, has received major emphasis in the present study involving testing the practicability of planting of conifer seedlings and two dicotyledonous species in uncultivated soil shortly after spraying the undesired vegetation. Additional work with certain soil applied herbicides and some planting modifications differing from those noted by earlier workers were included to enable comparisons of potential feasibility of various associated approaches to the problem.

I. MATERIALS AND METHODS

A. Description of Field Sites

A1. Mayberne

This site in the foothills of Alberta, in the northern region of the McLeod River basin, was 41 km N.W. of Edson on the Silver Summit road (SW33-56-18-W5). Plots were located adjacent to a mature lodgepole pine forest in an area clear-cut in 1967 and drag scarified in 1970. Soils, classified in the Luvisolic order, have developed on cobbly, morainal deposits, with drainage being moderately well to imperfect and texture loam to sandy clay loam.

The site had considerable variation in ground cover, including heavy grass (usually on 8 to 15 cm of organic matter), deadfall, alder (Alnus sp.) clumps and patches of exposed mineral soil supporting scattered forbs. The dominant plant species was marsh reed grass.

Density of grasses and other species was variable from place to place. In 5 random samples on June 16, 1976, grass stem counts ranged from 172 to 603 per m^2 and height varied from 15 to 43 cm. On the same date in 1977 new growth appeared to have started earlier than in 1976 and there were 549 to 1,356 stems per m^2 with heights of 30 to 136 cm in 4 random samples taken adjacent to the plots.

Chemical analysis of a sample of the upper 15 cm of mineral soil were performed by the Alberta Soil and Feed Testing Laboratory and are shown in Table 1.

TABLE 1 Mayberne Soil Test Results**

Available Plant Nutrients*					
N	P	K	pH	Conductivity (mmhos)	O.M.
1	18	103	4.9	0.1	Low +

* kgs of nutrient per 1 million kgs of soil.

A list of major species present in the different study areas appears in Appendix I.

A2. Stony Plain

This site was chosen in undulating farmland, 9.5 km south of the town of Stony Plain on Meridian road (SE36-51-1-W5). The plots were established on heavily sodded farmland which had been uncultivated for 15 years prior to commencement of the experiments. Soils of this well drained sandy loam site have developed on pitted deltaic material and are classified as Dark Gray Chernozemic.

Table 2 shows the results of a soil test on the upper 15 cm of the mineral profile.

TABLE 2 Stony Plain Soil Test Results

Available Plant Nutrients*					
N	P	K	pH	Conductivity (mmhos)	O.M.
3	61	192	6.7	0.1	Low

* kgs of nutrient per 1 million kgs of soil.

** See Appendix II for interpretation of Soil Test Results.

The dominant grasses at this location were creeping red fescue (Festuca rubra L.), Kentucky blue grass (Poa pratensis L.), quack grass (Agropyron repens (L.) Beauv.) and northern wheat grass (Agropyron dasystachyum (Hook.) Scribn.). The stem count, in 3 randomly selected quadrats, on June 18, 1976, ranged from 2,163 to 2,637 per m^2 and the height range was 7 to 48 cm. On June 1, 1977, the stem count ranged from 1,604 to 2,842 per m^2 and the height varied from 8 to 35 cm in 4 randomly selected quadrats.

A3. Grande Prairie

The topography surrounding this study area, in the Wapiti River valley, is classified as rough broken with a complex of slopes and benches. The plots were established on a level and uniformly vegetated bench on Alberta Power Ltd. right-of-way, 12 km south of the city of Grande Prairie, on the Resources road (SW29-70-5-W6). Soils in the immediate area are classfied as a complex association. The soil texture was loam to sandy clay loam and the site was considered well drained. Chemical analysis of a sample of the upper 15 cm of the mineral profile is shown in Table 3.

TABLE 3 Grande Prairie Soil Test Results

Available Plant Nutrients*					
N	P	K	pH	Conductivity (mmhos)	O.M.
1	3	201	8.2	0.2	Medium

*kgs of nutrient per 1 million kgs of soil.

A mature, dense aspen forest was adjacent to the heavily grassed site; the dominant species was creeping red fescue. Other prevalent grasses included timothy (Phleum pratense L.), crested wheat grass (Agropyron cristatum (L.) Gaertn.) and common bromegrass (Bromus inermis Leyss.). Stem counts of the grasses in 3 randomly selected quadrats, on June 22, 1976, indicated an average of 5,791 stems per m^2, with the height range being 25 to 58 cm. The following year on June 8, 4 random stem counts showed a range of from 3,487 to 4,316 stems per m^2 with a height range of 14 to 46 cm.

A4. Pass Creek

This study area was on a terrace of the Athabasca river, in a mixed-wood forest region 19 km south of Highway 43, along secondary Highway 947 (SE10-60-18-W5). The plots were established in an open site, which has supported very little tree growth since the spruce forest burned 25 years ago. Soils, which are of the Luvisolic order, have developed on fluvial deposits having a loam to sandy loam texture. The soil surface is covered by a thin organic layer.

Chemical analysis of a sample of the upper 15 cm of the mineral profile is shown in Table 4.

TABLE 4 Pass Creek Soil Test Results

Available Plant Nutrients*					
N	P	K	pH	Conductivity (mmhos)	O.M.
4	33	56	5.5	0.1	Low +

* kgs of nutrient per 1 million kgs of soil.

A high water table has resulted in a dense stand of, dominantly, marsh reed grass and various sedge species. Five random quadrats scored on June 15, 1977 indicated the number of stems per m^2 ranged from 1,270 to 1,690 with height varying from 10 to 37 cm.

A5. Economy

This site was in a cut block, in the Grande Prairie forest district, beside the forestry trunk road, at "mile 42", 74 km south of Highway 34 (NW29-65-2-W6).

The area, previous to harvesting, was mature spruce site. Dense growth of alder and willow that resulted after cutting had been brushed and the site was windrow scarified in the winter of 1974/75. During the ensuing summer 3 year old lodgepole pine seedlings were machine-planted in the cut block by Alberta Forest Service personnel. Soils on this site are classified either as Eluviated Eutric Brunisols or Brunisolic Gray Luvisols and have developed on glacial fluvial parent geological material. The site is imperfectly drained which results in saturated soils, except during dry periods.

Vegetation consisted of moisture tolerant species such as marsh reed grass, drooping wood reed (Cinna latifolia (Trev.) Griseb.) and Carex sp. The height of the grass on August 6, 1976 ranged from 100 to 150 cm.

B. General Materials and Methods

B1. Herbicide* Application

Spraying of all field plots (with exceptions noted where appropriate) was accomplished with a hand-held spray wand, with a 4 nozzle T-bar boom attachment, capable of spraying a 1.22 m swath. This spray boom, which was capable of applying 1.2ℓ per minute, was adapted to a standard 5ℓ plastic compressed air garden sprayer pumped with a constant number of strokes prior to each application. Preparation before each experiment included a number of "dry runs" on which walking speed was adjusted in order to apply all of the specified pre-measured volume of spray mixture on each plot. This operation involved spraying in both directions along the plot length. The herbicide and water were measured and mixed at the site just prior to spraying. During the spraying operation the boom was held approximately 5.5 dm (22") above the vegetation and the spray pattern was at a slight forward angle. Rate of application of spray mixture was 325ℓ/ha. (29 gal./A), except where noted later.

B2. Scalping Procedure

Scalps were prepared using a small hand mattock, to remove vegetation and dead organic matter above mineral soil, thus producing a slope-sided spot, with approximate area of 9.29 dm^2 (1 $ft.^2$), into which the desired species was planted.

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* Appendix III - List of Herbicides

B3. Seedling Description

Year old white spruce and lodgepole pine seedlings for the Mayberne site were obtained from North Western Pulp and Power Limited at Hinton, Alberta. Initial heights of the spruce seedlings were 4 to 8 cm in 1976 and 2.5 to 5 cm in 1977. Pine seedlings at planting time were 7 to 13 cm tall in 1976 and 4 to 9 cm in 1977.

For experiments other than at Mayherne, seedlings were provided by the Oliver Tree Nursery near Edmonton, Alberta. In 1976, yearling white spruce, 6 to 11 cm tall and lodgepole pine 4 to 9 cm tall, were used. In 1977, 2 year old stock of white spruce, 5 to 10 cm tall, and 1 year old lodgepole pine 4 to 11 cm tall were planted in respective experiments. All seedlings used in this project were grown in Spencer-Lemaire fold-up plug trays, except as noted later.

B4. Planting Methods

Except as noted under the descriptions of certain individual experiments the planting of all coniferous seedlings was accomplished using a dibble to form an opening in the soil. The seedling was inserted such that the root collar was at or below the soil surface. The dibble opening was firmly closed around the seedling peat plug with the back of an axe head to prevent air pockets from remaining around the roots.

B5. Precipitation Data

Table 5 indicates precipitation received at the weather station nearest to each experimental site during the growing seasons of 1976, 1977 and data for the 29 year average (1941-1970).

TABLE 5 Comparison of Total Precipitation in mm for 1976, 1977 and the 29 Year Average (1941-1970) for May through August

Weather Station	Distance in km from study site	1976	1977	29 year average
Mayberne	4	403	466	360
Stony Plain	15	325	422	267 (Edm. Mun. Airport)
Grande Prairie	14	359	320	215
Pass Creek	17	--	587	340
Economy	13	386	381	294

B6. Conifer Measurements and Observations

The securing of data in this project was accomplished by measuring height and weight and by observations of condition and survival of trees.

In all experiments with conifers in 1976, initial height measurements at planting time, heights in August of the same year, and final height measurements in the fall of 1977, were taken. Both spruce and pine were measured from the first growth node above the crown to the tip of the tallest terminal leaf. Exceptions to this procedure are noted for certain individual experiments.

Conifers planted in 1977 experiments were measured for leader length in the fall. Morphological variation between pine seedlings necessitated the establishment of the following criteria for measurement of leader length. Measurements were taken from:

- the previous year's bud scales, or
- the upper limit of the previous year's leaves, or
- the point on the stems where the color changed from brownish green (previous year's wood) to a lighter yellow green (current year's growth),

to the tip of the current year's bud.

Leader lengths of spruce were measured from the uppermost whorl of branches to the tip of the current year's bud.

On final measurement and observation days, during the fall of 1977, coniferous and deciduous trees at all experimental sites except Mayberne and Pass Creek were pulled, enclosed in labelled, airtight plastic bags and taken to the laboratory. Spruce and pine were clipped at the first growth node above the crown and the stems and leaves were weighed fresh. Conifers, less the root portions, were placed in paper bags and dried at 51.3°C for 72 hours before recording dry weights.

Caragana and willow were clipped at the crown and all dead branches were removed from the stems. Fresh and oven dry weights were taken as for the conifers.

In order to assess the health and vigor of the conifer seedling at the termination of each experiment, a set of condition categories was developed. Each conifer seedling was assigned to one of these condition categories. The description of each condition category is outlined below together with its rating code.

Rating Code	Conditional Code Description	
0	healthy:	up to 10% dead leaves on the base of the stem allowed.
1	good:	0 to 25% dead leaves
2	fair:	25 to 50% dead leaves
3	poor:	50 to 99% dead leaves
4	dead	

B7. Plot Ratings

The success of each vegetation control method, including herbicide treatments and scalps was determined by visual assessment. Each plot was assigned a rating based on the following description. Pluses and minuses were also assigned to each plot rating code to produce a more detailed rating.

Rating Code	Code Description	
0	very poor:	0 to 25%* control
1	poor:	25 to 50% control
2	fair:	50 to 75% control
3	good:	75 to 99% control
4	excellent:	100% control

* Percent control indicates the percent of vegetation killed compared with adjacent non-treated area.

B8. Method of Data Analysis

All experiments in this project were of the randomized block design (exceptions are indicated where appropriate). Data were statistically analysed by the Analysis of Variance method in order to determine if there were significant differences between any treatments within the experiment. Duncan's New Multiple Range Test was then used to determine which treatments were significantly different. All analyses were carried out through the Michigan Terminal System (MTS) of the AMDAHL 470V/6 computer operated by Computing Services of the University of Alberta.

The means of each treatment (calculated on the basis of the original number of trees planted per plot), within each block were determined and were used in the statistical tests. However, in order to increase the precision with which the Analyses of Variance test could detect significance, measurement data from some experiments were grouped into subsets within each plot. The means of these subsets (calculated on the basis of the original number of trees planted per subset) were then used in the statistical tests. The number of subsets per plot and the number of components per subset varied with the nature of each experiment and are reported under the description of each experiment.

C. Glyphosate Treatments

C1. Effects of Spring Treatment on Competing Vegetation and Survival and Growth of Implanted Conifer Seedlings with and without Scalping and Fertilization (1976)

C1a. White Spruce at Mayberne

In this single block experiment, 10 treatments, involving spot and strip applications, were established on June 15, 1976 to determine the effects of glyphosate, scalping, and fertilization on spruce and the grasses and forbs present. Each of the following treatments was applied within an area measuring approximately 1.2 x 50 m. Extreme ground cover variation prevented ideal lay-out of plots and resulted in some treatment rows involving treated spots, being longer or shorter than 50 m. Spot treatments included glyphosate applied on 28 and 56 cm diameter areas. These treatments were established to determine if treatment of small areas around a tree would result in benefits to the seedling. In addition there were 1.2 x 25.3 m strips, scalps and untreated controls. The 1.2 m strips were established to determine the effects of more extensive killing of competing vegetation. Scalps were included to act as a "standard control", as they are presently used in practical regeneration programs.

The 28 and 56 cm diameter spots were treated by placing an appropriately sized metal cylinder spray guide over the vegetation and spraying evenly inside. The spray mixture was applied with a 10 ml capacity continuous pipetting syringe sprayer (Corns 1976).

Strips were treated as noted under section B1. The rate of application of glyphosate in all treatments was 4.5 kg a.i./ha (4 lb. a.i./A) in 325ℓ/ha (29 gal/A) of spray mixture. On the basis of previous work (Corns and Cole 1973 and Valgardson and Corns 1974) this dosage was selected with the anticipation that it should be enough for initial complete control of treated herbaceous vegetation. It was also expected that there would be no troublesome residual effect in the soil from foliar glyphosate treatments applied shortly before planting the conifers in uncultivated soil. A main objective in this experiment was not to determine minimum effective dosages of glyphosate but to learn what benefits there might be for the young conifers from the various techniques during a period of absence of competing vegetation near the planted seedlings.

The foregoing treatments were repeated with the addition of one, 9 gram, 22-8-2, "Agriform" fertilizer tablet, inserted within about 2 cm of the upper 10 cm of each spruce seedling plug. Additional nutrients in the tablets included: Ca - 3.0%, S - 1.0%, Fe - 0.5% and Zn - 0.1%.

The day after spraying, the spruce measurements were recorded and the seedlings were planted using a dibble tube having a split point opened by a foot pedal, as each seedling was inserted into the tube. Placement of the seedling was followed by heeling in of the open space around the peat plug. Fifty spruce seedlings were planted per treatment. The seedlings were planted into the centers of the previously marked spots and scalps within the respective rows. Spruce in the control rows were planted on approximately 0.9 m centers. Spruce in treated strip plots were planted approximately 0.4 m apart along the centre of the strips.

Final height measurements, survival counts, condition ratings and plot evaluation were made on August 8, 1977. The measurements within each treatment were combined as 5 replicates with 10 spruce seedlings each for analysis as a randomized block experiment.

C1b. White Spruce at Stony Plain

The materials and methods used in this experiment were similar to experiment C1a. with the following exceptions. Date of spraying and scalping was June 18, 1976 with the spruce being planted the next day. The conifer seedling peat plugs were wrapped in 2.5 cm diameter clear plastic cylinders (peat sausages). The plastic wrapper was removed at planting time. Measurements were gathered on July 28, 1977 in the manner outlined in section B6.

C1c. White Spruce at Grande Prairie

The materials and methods used in this experiment were also similar to experiment C1a. at Mayberne, but with fewer treatments. Treatments were glyphosate treated strips, 1.2 x 25.3 m and rows of approximately that same length for scalps and controls. Each of these treatments was repeated with a fertilizer treatment. Scalping and spraying operations took place on June 21, 1976 with planting of the conifers being completed on the next day. Final measurements and observations were taken on August 17, 1977 in the manner outlined in section B6.

C1d. Lodgepole Pine at Mayberne

This experiment was adjacent to and of the same design as experiment C1a.

C1e. Lodgepole Pine at Stony Plain

This experiment was adjacent to and of the same design as experiment C1b.

C1f. Lodgepole Pine at Grande Prairie

This experiment was adjacent to and of the same design as experiment C1c.

C2. Effects of Late Summer Treatments on Competing Vegetation and Survival and Growth of Lodgepole Pine with and without Scalps (1976)

C2a. Mayberne

The purpose of this experiment was to determine if glyphosate and scalp treatments later in the growing season have a differential effect on weed control and pine as compared with similar treatments earlier in this season. Three blocks, each receiving 3 randomized treatments, including a 1.2 x 25.3 m glyphosate treated strip, unsprayed scalps and a control, were established on August 21, 1976. Glyphosate was applied at 4.5 kg a.i./ha.

On the day after spraying, each plot was planted with 50 pine seedlings on 0.45 m spacings in each row. Rows were approximately 3.1 m apart.

Final height measurements, tree condition ratings and plot weed control ratings were recorded on August 9, 1977. For the purpose of statistical analysis, the data within each plot were grouped into 5 subsets and the mean of each subset was calculated and used in statistical tests as outlined in section B8.

C2b. Stony Plain

This experiment was the same as C2a. except that the spraying and scalping date was August 3, 1976. Final measurements and observations were taken exactly one year later.

C3. Vegetation Control in Scalps with and without Treatment

C3a. Stony Plain

In order to determine if vegetation control in scalps could be improved by treatment of the surrounding vegetation with glyphosate, this experiment was established on June 1, 1977 with 3 randomized blocks with 2 treatments each. The treatments included 10 scalps not treated in one plot and 10 scalps within a 1.2 x 9.1 m plot treated immediately after scalping with glyphosate at 4.5 kg a.i./ha. The plots were visually assessed on August 23 of the same year and assigned a weed control rating as outlined in section B7.

C3b. Pass Creek

This experiment was identical to experiment C3a. Spraying and scalping occurred on June 15 and plot ratings were recorded on August 19.

C4. Effects of Spring Treatments on the Survival, Condition and Growth of Lodgepole Pine Seedlings (1977)

C4a. Stony Plain

Glyphosate was applied on June 1, 1977 and pine was planted the next day in order to determine if pine would be injured by this treatment as in similar experiments in 1976. This experiment consisted of 3 randomized blocks each containing a control and glyphosate treatment. Glyphosate was applied at 4.5 kg a.i./ha. to a 1.2 x 12.6 m strip. Twenty pine seedlings were planted at 0.45 m intervals in one row per plot.

Measurements and condition observations were taken on August 23, 1977. For statistical analyses the measurement data from each plot were divided into 5 subsets as noted for preceding experiments.

C4b. Stony Plain - Delayed Planting

This experiment was set up to determine if glyphosate applied six days prior to planting would result in injury to pine. Spraying date was June 1, 1977. Materials and procedures used in this experiment were identical to experiment C4a.

C4c. Pass Creek

An experiment similar to C4a. was conducted at this location. The spraying date was June 15, 1977 and pine seedlings were planted 3 hours after spraying. Fifty pine seedlings were planted per plot. Sixty five days after spraying, the final measurements and observations were made. Data were not statistically analysed because of obvious differences between the treatments.

C5. Comparison of Different Rates of Application on Competing Vegetation and on Lodgepole Pine (1976-1977

C5a. Mayberne - Planted 10 Months after Spraying

The primary purpose of this experiment was to determine the effectiveness of glyphosate applied at various dosages, in August, in controlling the grasses and forbs present. Triplicate randomized blocks, each containing 5 treatments were sprayed on August 1, 1976. The treatment consisted of glyphosate at 1.1 (1), 2.2 (2), 3.4 (3), 4.5 (4) and 5.6 (5) kg a.i./ha (lb/A). The sprayed strips measured 1.2 x 12.6 m.

To determine the possible benefits or injurious effects of the glyphosate treatments, 20 pine seedlings were planted on May 10, 1977, into the 4.5 kg/ha strips and an equal number were planted into untreated grass near each replicate. The seedlings were planted 0.6 m apart.

Final measurements and observations were obtained on August 29, 1977. The data were grouped into subsets as in experiment C4a.

C5b. Stony Plain - Planted 10 Months After Spraying

This experiment; similar to experiment C5a. was established at the Stony Plain site on August 21, 1976. Pine seedlings were planted on May 18, 1977, approximately 9 months later. Final measurements and observation were made on August 23, 1977.

C5c. Stony Plain - Planted Immediately After Spraying

The purpose of this experiment was to determine the possible injurious effects of various dosages of glyphosate on pine seedlings planted immediately after spraying.

Duplicate,randomized blocks each containing six 1.2 x 6 m plots were established on June 21, 1977. The treatment rates included 0.0, 1.1, 2.2, 3.4, 4.5 and 5.6 kg a.i./ha. Ten pine seedlings were planted in each plot 3 hours after spraying.

Measurements and observations were made 64 days after spraying. Measurement data were grouped into 5 subsets within each plot with the possibility of 2 surviving trees occurring within each subset.

C5d. Economy - Planted One Year Previous to Spraying

An experiment with glyphosate at 1.1 to 5.6 kg/ha similar to experiments C5a. and C5b. was established at this location on August 6, 1976. Three year old lodgepole pine seedlings had been machine planted on 2.7 m centers in the summer of 1975 by the Alberta Forest Service. Nineteen of these pines occurred randomly throughout the plots and leader length measurements and condition observations were taken on August 30, 1977. Similar measurements and observations were taken on 13 pine seedlings occurring in the untreated grass, adjacent to the treated plots.

C6. Effects on Lodgepole Pine in Greenhouse and Growth Chamber Experiments at Edmonton

This series of experiments, conducted at the University of Alberta, was initiated to study further, the problem of injury to lodgepole pine seedlings planted in glyphosate treated plots.

In all of the greenhouse experiments, the procedure for the application of glyphosate was the same with exceptions as noted where appropriate. Each pot or flat requiring treatment was placed inside a 9.29 dm^2 (1 $ft.^2$) spray guide and the spray mixture was applied evenly within that area. Some or all of the following dosages used were: 2.2, 4.5, 6.7 and 9.0 kg a.i./ha. Application was accomplished with delivery of respective volumes from a 10 ml capacity continuous pipetting springe sprayer (Corns 1976).

Lodgepole pine seedlings used in the greenhouse experiments were from the same stock as the pine used in 1977 field experiments, other than at Mayberne (B8). White spruce and lodgepole pine seed used in the greenhouse experiments were obtained from the Oliver Tree Nursery. Pine germination was 91%, white spruce 69%.

Experiments were conducted either in the greenhouse or in a walk-in growth chamber. In the greenhouse the intensity of natural lighting in the spring and fall was from 93 to 149 lux and light intensity in the winter and summer was 28 and 464-743 lux, respectively. Supplemental lighting was provided for 16 hours per day and the temperature was maintained at 23°C.

Light intensity in the growth chamber was 186 lux with a duration of 16 hours per day. Temperature was maintained at 25°C.

Except as noted, the watering of experiments was carried out on a daily basis and fertilization with a liquid fertilizer mixture (20-20-20) was applied approximately once every two weeks by greenhouse staff.

C6a. Effects on Pregerminated Lodgepole Pine Seed

To determine the effects of glyphosate on survival and continued growth of pregerminated pine seed, 2 randomized block experiments were established. In a preliminary trial medium sand and a 1:1:1* greenhouse soil mixture was firmed into 5 x 7 cm plastic flats. The flats were filled to within 1.5 cm of the top. Treatment included glyphosate sprayed

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* Soil:Organic Matter:Sand

24 hours after planting, at both the 2.2 and 4.5 kg/ha rate.

Pine seedlings were germinated by placing the seed on moist filter paper in 14 cm diameter covered petri dishes. Pregerminated seed with radicle lengths of approximately 1.0 cm were planted, six per flat, to a depth of 0.5 cm. Immediately before spraying, the soil was saturated with water. The experiment was placed in the greenhouse compartment for 71 days after which time the survivors were counted and growth was recorded by height measurements from the crown to the tip of the tallest terminal leaf.

In view of the results of the preliminary experiment, a second experiment with 3 replicates and 2 soil types was set up to provide additional information on the effects of glyphosate on pregerminated pine seed. Procedures in this second experiment were similar to the first experiment except that glyphosate was applied on May 26, 1977 at 0.0, 2.2, 4.5, 6.7 and 9.0 kg a.i./ha 24 hours after planting 20 pregerminated pine seeds per 14 x 14 cm flat in 3:1:1 and 1:1:2 greenhouse soil mixtures. The experiment was placed in the growth chamber for 50 days, at which time survivors were counted and growth was measured by taking height and fresh weights.

C6b. Effects on Germination and Growth of Lodgepole Pine - Not Pregerminated

A preliminary experiment was established to test the effects of glyphosate on seed germination and subsequent seedling growth of lodgepole pine. This experiment was similar to the second experiment of C6a. and used 2:1:1 soil with glyphosate dosages of 2.2 and 4.5 kg a.i./ha. Final measurements of pine were taken 91 days after treatment.

A second set of experiments was established like the preliminary experiment except for the addition of 6.7 and 9.0 kg a.i./ha dosages of glyphosate and use of 3:1:1 and 1:1:2 soil mixtures. Final measurements of pine were taken 50 days after treatment.

C6c. Effects on Lodgepole Pine Seedlings Planted in Different Soils After Spraying the Soil

Duplicate, randomized blocks, each consisting of 5 treatments, were established on May 25, 1977. Five soils were used in this experiment, including the greenhouse mixtures, 1:1:2 and 3:1:1, and soil from the Mayberne, Stony Plain and Pass Creek sites. The field soils were taken from the top 15 to 20 cms of the mineral profile at each site. Each soil was placed into 10, standard 20 cm diameter plastic pots with drainage. All soils were firmed into the pots, watered to field capacity and sprayed immediately with glyphosate. The rates of application received by each soil were 0.0, 2.2, 4.5, 6.7 and 9.0 kg a.i./ha.

Twenty four hours after spraying, pine seedlings were measured from the first growth node above the crown to the tip of the bud and planted, 4 per pot, with a dibble. The experiment was placed in a greenhouse compartment.

For the first week, the pots were watered twice daily to maintain the soils at field capacity. The trees were periodically measured to record continued growth. On

September 8, the final measurements and observations were made, which included: height (from the first growth node above the crown to the tip of the terminal bud), fresh and dry weights and a condition rating which was assigned to each pine as outlined in section B6. The initial height measurements were subtracted from the final height measurements to obtain growth. The mean growth and weight per tree, per pot (based on 4 pines per pot) were calculated and statistical analysis was carried out on these data.

In a second experiment similar to the one presented above, spraying was done on July 12, 1977. This experiment consisted of 4 replicates and included soils from the Stony Plain field site and greenhouse mixtures, 3:1:1 and 1:1:2. Rates of application of glyphosate were 0.0, 1.1, 2.2, 4.5 and 6.7 kg a.i./ha. Final height measurements were taken on August 26, 1977.

C6d. Survival and Growth of Lodgepole Pine Seedlings Under Treated and Sprinkled Grass

This experiment was established to determine if glyphosate treated grass, placed above pine seedlings and repeatedly sprinkled with water to simulate rainfall run-off would cause injury to pine. The experiment was established by planting 24 pine seedlings per flat in 6, deep wooden flats (15 x 31 x 46 cm), on May 31, 1977. On June 14, 1977 actively growing wheat (48 to 61 cm in height) grown in 2:1:1 soil in 6 standard wooden flats was treated with glyphosate as follows: 2 flats received no glyphosate, 2 flats received 4.5 kg a.i./ha and 2 flats were sprayed at 9.0 kg a.i./ha. One day later the wheat stems and leaves for the respective pine flats were clipped 2 cm above the soil surface and suspended approximately 6 cm above the lodgepole pine seedlings by means of standard bug screening stretched over a wooden support frame.

To simulate 1 cm of rain per day for the first week of the experiment and periodically thereafter, the treated wheat leaves were sprinkled with 1426 ml of water per flat.

On September 9, the pine seedlings were measured and weighed in a manner similar to that involved in experiment C6c. Statistical analysis was conducted on the basis of 2 blocks each containing 4 subsets.

C6e. Survival and Growth of Lodgepole Pine Seedlings in Contact with Treated and Sprinkled Grass

This experiment was set up to determine if glyphosate treated grass leaves and stems, subsequently kept in direct contact with pine seedlings and sprinkled with water, would have an injurious effect on pine. Otherwise procedures and materials used, were similar to those in experiment C6d.

C7. Tolerance of Conifers to Direct Treatment

C7a. Lodgepole Pine in the Greenhouse

The purpose of these experiments was to determine the effects on survival of pine receiving direct application of glyphosate at various rates. Pine, used in the preliminary experiment, was seeded on October 14, 1976 in wooden flats (15 x 31 cm) and transplanted, 4 per 5 x 7 cm plastic flat in 1:0:1 soil, 14 weeks later. This experiment consisted of a single block with six plastic flats per treatment rate. The treatments included 0.0, 1.1, 2.2, 3.4, 4.5 and 5.6 kg a.i./ha. On treatment day (March 8, 1977) the pine measured from 2 to 4 cm in height. The experiment was placed in the greenhouse compartment and survival counts and observations were carried out periodically with the final count and observation on June 11.

In a second experiment, there were also a number of soil treatment herbicides as noted under section D. Rates of application of glyphosate were 0.0, 1.1, 3.4 and 6.7 kg a.i./ha on young seedling conifers. Other details of preparation are consolidated under experiment D2a.

C7b. White Spruce and Lodgepole Pine in the Field at Ellerslie

In this field experiment glyphosate was again included with a number of soil treatment herbicides. The rates of application of glyphosate were 0.0, 2.2, 4.5 and 6.7 kg a.i./ha. Other details corresponded to those noted under experiment D2b.

C8. Effects of Treatments on Survival and Growth of Newly Planted Deciduous Species

C8a. Willow at Stony Plain

The purpose of this experiment was to observe the effects on survival and growth of acute-leaved willow planted one day after glyphosate treatment. Five treatments were applied within a single block on June 18, 1976. The treatments included untreated scalps, an undisturbed control, glyphosate applied at 4.5 kg a.i./ha in 28 cm diameter spots and in 0.6 and 1.2 x 25.3 m wide strips.

Fifty, 1 year old rooted willow cuttings were planted 0.45 m apart, in one row per treatment, the day after spraying, in rows 2.1 m apart. Slits in the sod for the bare rooted cuttings were made with a wedge planting bar. After planting the bar was inserted near the plant and pressed forward to close the planting slit tightly. After planting, the willows were pruned to a height of 18 cm above the ground level. On July 26, 1977 the percentage survival was determined and the willows were harvested for fresh and dry weights, after removal of any twigs of the previous year that were winter-killed.

The data from each treatment were analysed statistically, using 5 replicates each representating 10 initial plants.

C8b. Willow at Grande Prairie

This experiment was identical to experiment C8a. Spraying and scalping date was June 21, 1976 and harvest was August 17, in the next year.

C8c. Caragana at Stony Plain

The purpose, material and methods used in this experiment were similar to experiments C8a and C8b, with the following exceptions. Two year old caragana seedlings obtained from the Oliver Tree Nursery were planted one day after spraying in 2 blocks each containing 2 treatments. The treatments were a control and a 1.2 x 25.3 m strip of glyphosate sprayed at 4.5 kg a.i./ha on June 1, 1977. Harvest date was August 23 of the same year

C8d. Caragana at Grande Prairie

This experiment was identical to C8c. with the following exceptions. Eight month old caragana seedlings grown in the greenhouse were planted on June 8 and harvested on August 17.

D. Soil Treatments

D1. Effects of Herbicides and Scalping on Competing Vegetation and on Survival, Condition and Growth of White Spruce and Lodgepole Pine

Suitable soil treatments, that could be tolerated by conifers, would avoid the problems associated with foliar applications of herbicides, such as waiting until the weedy vegetation is ready to spray and then requiring favorable weather during the operation, plus absence of rainfall immediately afterwards that could wash off much of the herbicide. Accordingly, the following series of experiments was performed to investigate possibilities for successful use of certain soil treatments.

D1a. Simazine and Karbutilate at Mayberne

A triplicate, randomized block experiment with each block containing 6 treatments in 1.2 x 12.2 m plots was established on July 6, 1976. The treatments included karbutilate 4% granular applied at 7.8 and 15.7 kg a.i./ha, simazine 4% granular applied at 15.7 and 31.4 kg a.i./ha, scalps and a control. Before the herbicides were applied, each planting spot was covered with a 28 cm diameter paper plate to prevent the herbicides granules from falling into the immediate planting area. The herbicides were distributed evenly over each plot, by hand, with a shaker can. On the same day as the herbicides were applied, 17 spruce and 17 pine seedlings were measured and planted in each plot. Within each plot, the spruce and pine were planted parallel to one another on 0.6 m centers, 0.4 m apart and 0.4 m from the plot edge. As a result of variable ground cover some variation in this planting arrangement occurred.

Periodic observation of plot weed control and conifer condition were made during the growing season of 1976 and 1977. Final plot weed control ratings and tree measurements and observations were made on August 28, 1977. The mean growth per tree per plot was determined and these data were subjected to statistical analysis.

Dlb. Velpar at Grande Prairie

The site chosen for this experiment differed from the site of the other experiments at Grande Prairie. A dense stand of marsh reed grass, growing on 10 to 15 cm of organic matter, covered the site.

This experiment consisted of two blocks with 4 Velpar dosages each, applied on September 3, 1976. Velpar 10% granular was applied, by hand, with a shaker can, at 2.2, 3.4, 4.5, and 5.6 kg a.i./ha to 2.13 x 2.13 m plots.

On June 8, in the following year, all Velpar treatments plus control plots adjacent to each block were planted with 10 spruce and 10 pine seedlings per plot. The planting was done evenly within each plot with the spruce and pine planted 20 to 25 cm apart. Harvest and plot ratings were accomplished 56 days after the conifers were planted. Height measurement data within each plot were grouped into 5 subsets for statistical analysis.

D1c. Simazine, Atrazine and Velpar Applied as a Mixture and Separately at Pass Creek

The purpose of this experiment was to compare effects of certain herbicides alone or in a mixture with regard to vegetation control and conifer tolerance. A suitable mixture with components having different properties and speeds of action might ideally provide both early and long lasting vegetation control while at the same time permitting healthy establishment of the planted seedling. To investigate the foregoing possibilities the following experiment included herbicides and a herbicide mixture applied at different dosages immediately before and after scalping, together with controls. The aim was to determine the advantages of planting seedlings in untreated spots versus treated spots, both with the surrounding vegetation sprayed. Each component of the herbicide mixture was also applied alone at a proper dosage to permit observation of evidence of differential activity of the components.

The experimental design was triplicate randomized blocks, each with 10 treatments. In addition to a control and scalp treatment, each block received the herbicide and scalping treatments before planting as shown in Table 6. Rate of application of spray mixture was 392ℓ/ha as outlined in section B1.

Twenty spruce and 20 pine seedlings were planted per plot with each spruce and pine seedling planted 10 to 15 cm apart. The pairs of conifers were planted on 0.6 m centers.

Periodic plot and tree condition observation were taken during the summer. Final measurements, tree condition ratings and plot weed control were recorded 37 months after spraying. The measurement data in each plot were grouped into 5 subsets prior to statistical analysis.

D1d. Velpar, Fluridone and Simazine - Atrazine - Velpar Mixture at Pass Creek

The major purpose for the establishment of this experiment was to supplement experiment D1c. by determining rates of application that adequately control the weedy vegetation found at this site.

Three randomized blocks containing 13 herbicide treatments were sprayed on April 30, 1977. The treatments included the following herbicides and dosages, which were applied to 1.2 x 9.8 m plots: Velpar 80% WP at 2.2, 4.5, 6.7 and 11.2 kg a.i./ha, fluridone 50% WP at 2.2, 4.5, 6.7, 9.0 and 11.2 kg a.i./ha and simazine-atrazine-Velpar mixture 86.7% WP at 2.2, 4.5, 6.7 and 9.0 kg a.i./ha.

A secondary purpose of this experiment was to get some preliminary information on the effects of various

TABLE 6 Herbicide Treatments - Experiment Dlc.

Herbicide**	% Active WP	Rate (kg a.i./ha)	Scalped**
Simazine	80	7.8	No
Atrazine	90	7.8	No
Velpar	90	7.8	No
Mixture*	86.7	7.8	No
Mixture*	86.7	7.8	Immediate after-spray
Mixture*	86.7	15.7	Immediate after-spray
Mixture*	86.7	7.8	Immediate before-spray
Mixture*	86.7	15.7	Immediate before-spray

* The herbicide mixture consisted of 2.5 parts active simazine, 2.5 parts active atrazine and 2.0 parts active Velpar.

** All chemical treatments were applied before planting.

herbicide dosages on spruce and pine in order to provide supplementary evidence for comparison with experiments Dlb. and Dlc. For this purpose some planting of these conifers was undertaken in the plots of 2 blocks sprayed with 4.5 kg a.i./ha of Velpar and in the 4.5 and 9.0 kg a.i./ha. rate of fluridone. Twelve spruce and 12 pine seedlings were planted per plot. Six of these 12 seedlings of each species were planted into scalps made immediately after spraying the strips. These scalps alternated with the planting spots of the remaining six seedlings of each species, which were planted directly into the sprayed sod. At each planting spot seedlings of the two species were planted 10 to 15 cm apart. Pairs of seedlings were planted approximately 0.6 m apart, as allowed by ground variation.

Final plot ratings, tree condition ratings and tree measurements were made 121 days after planting. Measurements in each plot were grouped into 3 subsets for statistical analysis.

Dle. Velpar, Fluridone and Simazine-Atrazine-Velpar Mixture at Mayberne

The experiment at this site, which was sprayed, scalped and planted on May 11 was similar to experiment Dld. with the following exceptions. Two blocks were established and the conifers were additionally planted in the Velpar plots treated with 11.2 kg a.i./ha and in the herbicide mixture plots treated with 4.5 and 9.0 kg a.i./ha. Final measurement and observation day occurred 110 days after planting.

D2. Tolerance of Conifers to Direct Treatment

D2a. Lodgepole Pine in the Greenhouse

In order to obtain pine seedlings for this experiment, seed was germinated and the resulting seedlings were grown for one month in 31 x 46 cm wooden flats. Seedlings were then transplanted to 2:1:1 soil in standard 10 cm diameter plastic pots. One seedling was planted per pot. On July 14, 1977 (five months after transplating), the herbicide treatments, shown in Table 7, were applied. Each treatment was applied to 10 pine seedlings in the manner outlined under section C6. As noted earlier, glyphosate was also included in this experiment and the results are reported under C7a.

This experiment was placed in the greenhouse where periodic survival counts were taken. The final survival count was taken on February 13, 1978.

D2b. White Spruce and Lodgepole Pine at Ellerslie

This single block experiment was conducted at the University of Alberta's farm at Ellerslie, on brome-quackgrass sod. Ten spruce and 10 pine seedlings were measured and planted on June 14, 1977 in 1.2 x 3.6 m plots. Spruce seedlings were planted 10-12 cm from pine seedlings. The position of each seedling, in each pair, alternated at each planting spot. Seedling pairs were planted 0.3 m apart in one row within each plot.

On July 8 the herbicide treatments that appear in Table 8 were applied to the conifer seedlings as direct

TABLE 7 Herbicide Treatments - Experiment D2a.

Herbicide	Formulation	% Active	Rate (kg a.i./ha)
Velpar	WP	90.0	0.0 3.4 6.7 10.1
Fluridone	liquid suspension	43.2	0.0 3.4 6.7 10.1
Mixture*	WP	86.7	0.0 5.6 11.2 16.8

* The herbicide mixture consisted of 2.5 parts active simazine, 2.5 parts active atrazine and 2.0 parts active Velpar.

TABLE 8 Herbicide Treatments - Experiment D2b.

Herbicide	Formation	% Active	Rate (kg a.i./ha)
Velpar	WP	90.	0.0
			3.4
			6.7
			10.1
Fluridone	liquid suspension	43.16	0.0
			3.4
			6.7
			10.1
Mixture*	WP	86.7	0.0
			5.6
			11.2
			16.8

* The herbicide mixture consisted of 2.5 parts active simazine, 2.5 parts active atrazine and 2.0 parts active Velpar.

sprays. The rate of application of the spray mixture was 336ℓ/ha. As noted earlier glyphosate was also applied in this experiment and the results are reported under experiment C7b.

Condition of the trees was checked periodically throughout the summer with final plot ratings and tree observation and measurements taken 61 days after spraying.

C. Glyphosate Treatments

C1. Effects of Spring Treatment on Competing Vegetation and Survival and Growth of Implanted Conifer Seedlings with and without Scalping and Fertilization (1976)

C1a. White Spruce at Mayberne

Herbaceous Vegetation Control

Two weeks after the 4.5 kg/ha glyphosate treatment the control of grass was excellent. A limited number of broadleaved plants, predominantly fireweed, persisted with varying degrees of herbicide damage after spraying. Three months after treatment there was "fair" (65-75%) vegetation control in the glyphosate spot treatments whereas "good" (75-99%) vegetation control was evident in the glyphosate strip treatments (Table 9). Vegetation reinvasion in the scalps was less than 25% therefore weed control in this treatment was also "good". Fourteen months after treatment, vegetation control in all plots was "fair" (50-75% control) except in the fertilized scalp and the 28 cm spot which had "poor" (40-50% control) weed control.

Plate 1 is representative of vegetation control maintained 14 months after treatment at this site in strips.

Survival and Condition

Spruce seedling survival was excellent. Percentages were from 82 to 96, with most data in the upper part of this range. The majority of surviving spruce in all treatments

TABLE 9 Effectiveness* of Vegetation Control in White Spruce and Lodgepole Pine Experiments-Cla., b, c, d, e and f.

Treatment	Mayberne (Cla. and d.)				Stony Plain (Clb. and e.)				Grande Prairie (Clc. and f.)			
	3 mos.		14 mos.		3 mos.		14 mos.		3 mos.		14 mos.	
	PL**	SW***	PL	SW	PL	SW	PL	SW	PL	SW	PL	SW
Control	0	0	0	0	0	0	0	0	0	0	0	0
Scalp	3	3	2	2	3	3	1	1	3-	3	2	2-
Glyphosate 4.5 kg/ha:												
28 cm diam. spot	2+	2+	2	2	2	2	0	0	-	-	-	-
56 cm diam. spot	2+	2+	2	2	2+	2	1	1	-	-	-	-
1.2 m strip	3	3	2	2	3	2+	1+	1+	3-	2+	1+	1
Control - fert.	0	0	0	0	0	0	0	0	0	0	0	0
Scalp - fert.	3	3	1+	1+	3	3	1	1	3	3	2	2
Glyphosate												
28 cm diam. spot-fert.	2	2+	1	1+	2	2	0	0	-	-	-	-
56 cm diam. spot-fert.	2+	2+	2	2	2+	2	1	1	-	-	-	-
1.2 m strip - fert.	3+	3	2+	2+	3	2+	1	1	2+	2+	1	1

* 0 - very poor: 0 to 25% control
1 - poor: 25 to 50% control
2 - fair: 50 to 75% control
3 - good: 75 to 99% control
4 - excellent: 100% control

** PL - Lodgepole pine
*** SW - White spruce

Plate 1 Vegetation Reinvasion at Mayberne (Cla) 14 Months After Spring Treatment with Glyphosate at 4.5 kg/ha

was assigned to the condition category 0-1 (healthy-good). Ninety-six percent of the fertilized spruce planted in scalps were placed in this condition category (Table 10).

Height Growth

Three months after treatment the mean height of spruce seedlings in the scalps with and without fertilizers and in the 56 cm glyphosate treated spot was significantly higher than spruce planted in the control and the 28 cm spot with fertilizer. Spruce in the scalps, fertilized and unfertilized, grew 17 and 23% more, respectively than spruce in the unfertilized control (Table 11). The mean height obtained by the spruce planted in these two scalp treatments was apparently greater; but not significantly greater than the height obtained by spruce in all other treatments.

In the fall of the second growing season (14 months after treatment), the mean height of spruce in the fertilized scalp treatments was significantly greater than the mean height of spruce in the unfertilized control, fertilized 28 cm spot and the strips both fertilized and unfertilized. Fertilized seedlings in scalps were 35% taller than seedlings in the control. Spruce in the unfertilized scalp achieved a mean height apparently greater but not significantly greater, than all other treatments except for the fertilized scalp and fertilized control.

Among the fertilizer treatments the control was the only one that was significantly better than its unfertilized counterpart and was equal to the fertilized scalp.

TABLE 10 Survival and Condition* of White Spruce Seedlings 14 Months After Treatments - Experiments Cla, b and c.

Treatments	Mayberne (Cla.)			Stony Plain (Clb.)			Grande Prairie (Clc.)		
	% Survival	Condition Categories		% Survival	Condition Categories		% Survival	Condition Categories	
		0-1	2-3		0-1	2-3		0-1	2-3
Control	82b**	78	4	80ab	48	32	98a	72	26
Scalp	94a	88	6	86ab	84	2	98a	92	6
Glyphosate 4.5 kg/ha:									
28 cm diam. spot	96a	90	6	78ab	46	32	--	--	--
56 cm diam. spot	90ab	78	12	70b	34	36	--	--	--
1.2 m strip	92ab	86	6	66b	30	36	80a	66	14
Control - fert.	98a	90	8	94a	68	26	100a	74	26
Scalp - fert.	96a	96	0	94a	84	10	98a	94	4
Glyphosate 4.5 kg/ha:									
28 cm diam. spot - fert.	86ab	66	20	64b	32	32	--	--	--
56 cm diam. spot - fert.	92ab	78	14	62b	34	28	--	--	--
1.2 m strip - fert.	96a	80	16	72ab	18	54	94a	90	4

* Condition is expressed as a percentage of spruce seedling assigned to each Condition Category. 0 - 1: healthy - good, 2 - 3: fair - poor.

** Percentages followed by the same letter are not significantly different at the 5% level using Duncan's Multiple Range Test (Duncan, 1955).

TABLE 11 Height* and Dry Weight** of White Spruce Seedlings After Various Treatments - Experiments Cla, b and c.

Treatments	Mayberne (Cla.)		Stony Plain (Clb.)			Grande Prairie (Clc.)		
	Height		Height		Weight	Height		Weight
	3 mos.	14 mos.	3 mos.	14 mos.	14 mos.	3 mos.	14 mos.	14 mos.
Control	100bc*** (5.7cm)	100c (7.2cm)	100ab (7.0cm)	100bc (8.4cm)	100bc (4.9gm)	100a (6.7cm)	100a (9.4cm)	100b (4.1gm)
Scalp	123a	124a-c	116a	117ab	154a	108a	100a	119b
Glyphosate 4.5 kg/ha:								
28 cm diam. spot	111a-c	120a-c	112a	84cb	89bc	--	--	--
56 cm diam. spot	115a	115a-c	95ab	72d	77bc	--	--	--
1.2 m strip	113ab	104c	106ab	78cd	92bc	99a	78b	93b
Control - fert.	112a-c	135a	106ab	112ab	106bc	103a	115a	99b
Scalp - Fert.	117a	135ab	112a	135a	168a	106a	118a	171a
Glyphosate 4.5 kg/ha:								
28 cm diam spot - fert.	99c	104c	86b	67d	66c	--	--	--
56 cm diam. spot - fert.	112a-c	110bc	94ab	72d	77bc	--	--	--
1.2 m strip - fert.	112a-c	108c	94ab	92b-d	113b	100a	99a	165a

* Height is expressed as a percentage calculated from the mean height per spruce seedling per treatment.

** Dry weight is expressed as a percentage calculated from the mean weight per replicate per treatment.

*** Percentages followed by the same letter are not significantly different at the 5% level using Duncan's Multiple Range Test (Duncan, 1955).

Plots treated with glyphosate did not significantly increase or decrease the growth of spruce seedlings during the first two growing seasons. The mean heights of these treatments were grouped closely together with a range of 20%.

C1b. White Spruce at Stony Plain

Herbaceous Vegetation Control

Top killing of grass in 4.5 kg/ha glyphosate treated plots, 12 days after spraying, was excellent. Three months after treatment, 35 to 40% reinvasion of vegetation had occurred in all spot treatments (Table 9). After the same length of time 25 to 35% vegetation reinvasion had occurred in both the strip treatments. Vegetation control in scalps after 3 months was "good" with less than 25% reinvasion. Plate 2 illustrates the extent of vegetation reinvasion at the Stony Plain site after 11 months. Fourteen months after treatment vegetation control in the scalps and all glyphosate treatments was "poor" (25 to 50% control).

Survival and Condition

The survival of spruce in fertilized controls and scalps (94% in both treatments) was significantly greater than survival of spruce in the fertilized 28 and 56 cm spots and in the unfertilized 56 cm spots and unfertilized strip (Table 10). Moreover, fertilized and unfertilized scalps had the best condition rating. Of the spruce in the fertilized control, 68 and 26% were assigned to the 0-1 (healthy-good) and 2-3 (fair-poor) condition category,

Plate 2 Vegetation Reinvasion at Stony Plain (Clb) 11 Months After Spring Treatment with Glyphosate at 4.5 kg/ha

respectively, while 84% of the spruce planted in the fertilized and unfertilized scalps were assigned to the 0-1 condition category. The surviving spruce seedlings in the glyphosate treatments were almost equally divided between the 0-1 and 2-3 categories.

Height Growth

Three months after treatment the mean height of spruce seedlings in the scalp treatments, both fertilized and unfertilized and in the 28 cm glyphosate treated spots was significantly higher than the mean height of fertilized spruce in the 28 cm spots (Table 11). No other treatments were significantly different after 3 months.

After 14 months the mean height of fertilized control plants and those in fertilized and unfertilized scalps was significantly greater than it was in any of the glyphosate treatments except the unfertilized 1.2 m strip. Fertilized spruce in scalps were significantly taller than spruce in any of the other treatments except the fertilized control and the unfertilized scalps. In the latter case however, the data seem to show a definite tendency to be smaller than for the fertilized scalps (117 vs 135% of control).

The data also indicate that any improvement by fertilizer was most evident during the year after the treatment. Fourteen months after treatment the dry weights of fertilized and unfertilized spruce in the scalps were significantly greater than the dry weights of spruce in all other treatments at Stony Plain (Table 11). Fertilized spruce in the scalps weighed 68% more than the controls while unfertilized spruce in the scalps weighed 54% more than the controls.

C1c. White Spruce at Grande Prairie

Herbaceous Vegetation Control

Similar to results of experiments C1a and b (Mayberne and Stony Plain) an almost complete top kill of grasses occurred within 2 weeks of spraying with 4.5 kg/ha glyphosate as illustrated in Plate 3. Three months after spraying there was a reinvasion consisting mainly of creeping red fescue in addition to many broadleaved plants as listed in Appendix I. Vegetation control in the strips was "fair" (65 to 75% control) whereas control in the scalps was "good" (75 to 99% control), (Table 9). Fourteen months after treatment, vegetation control in the strips was "poor" (35 to 40% control) while vegetation control in the scalps was "fair" (50 to 60% control).

Survival and Condition

Survival of spruce seedlings at Grande Prairie was not less than 94% in any treatment therefore there were no significant differences (Table 10). The percentage of spruce seedlings assigned to the 0-1 (healthy-good) condition category in the fertilized and unfertilized scalps and the fertilized strip ranged from 90 to 94. Sixty-six to 74% of the seedlings were assigned to this category in the remaining treatments.

Plate 3 Vegetation Control at Grande Prairie (Clc), Typical of All Sites, 2 Weeks After Spring Treatment with Glyphosate at 4.5 kg/ha

Height Growth

After 3 months there were no significant differences in the mean heights of spruce seedlings among the treatments (Table 11). After 14 months the mean height of spruce planted in the glyphosate treated strip was significantly less than all other treatments. The mean height of seedlings in the fertilized control and scalp treatment appeared to be 15 and 18% higher, respectively, than that of the control, but this increase was not found to be significant.

As in experiments Cla and b the fertilizer treatments seemed to stimulate the growth of spruce more in the second growing season than in the first.

Weight

Fourteen months after treatment the mean weight per replicate of fertilized spruce seedlings in the scalps and the strip was significantly greater than all other treatments. The weight of fertilized spruce in the scalp treatment was 71% greater than the control while the mean weight of fertilized spruce in the strip was 65% higher than the control. The mean weight of unfertilized spruce in the strip appeared to be less than in the control.

Cld. Lodgepole Pine at Mayberne

Herbaceous Vegetation Control

Weed control after the various treatments was "fair" (50 to 75%) in all plots 14 months after treatment similar to that noted for experiment Cla (Table 9).

Survival and Condition

In all treatments the percentage survival of pine seedlings after 14 months was greater than 94% therefore there were no significant differences between treatments. Seventy-six to 100% of the pine seedlings were assigned to the 0-1 (healthy-good) condition category (Table 12) with scalps having the highest percentages in the 0-1 category.

Height Growth

Three months after treatment the mean height of pine in the fertilized scalps was significantly greater than height of pine in all other treatments except for pine in the 56 cm spot and the strip plus fertilizer. The mean height of pine in fertilized scalps was 14% higher than the control (Table 13). The mean height of pine in unfertilized scalps was significantly less than it was in the fertilized scalps.

Fourteen months after treatment pine seedlings planted in the scalps and strip with fertilizer were significantly higher than pine in all other treatments except for pine in the fertilized control and fertilized 56 cm spots. Fertilized pine in all treatments except the 28 cm spot were 9 to 20% higher than the unfertilized control.

C1e. Lodgepole Pine at Stony Plain

Herbaceous Vegetation Control

Weed control in the various plots was "poor" or very poor 14 months after treatment, similar to that previously noted for experiment C1b.

TABLE 12 Survival and Condition* of Lodgepole Pine Seedlings 14 Months After Various Treatments - Experiments Cld, e and f.

Treatments	Mayberne (Cld.)			Stony Plain (Cle.)			Grande Prairie (Clf.)		
	% Survival	Condition Categories		% Survival	Condition Categories		% Survival	Condition Categories	
		0-1	2-3		0-1	2-3		0-1	2-3
Control	98a+	92	6	88a	52	36	88ab	58	30
Scalp	100a	100	0	86a	74	12	96a	74	22
Glyphosate 4.5 kg/ha:									
28 cm diam. spot	100a	90	10	22d	6	16	--	--	--
56 cm diam. spot	96a	76	20	30dc	8	22	--	--	--
1.2 m strip	100a	92	8	40cd	6	34	68b	42	26
Control - fert.	98a	94	4	74ab	42	32	84ab	40	44
Scalp - fert.	100a	96	4	82a	68	14	100a	80	20
Glyphosate 4.5 kg/ha:									
28 cm diam. spot - fert.	94a	80	14	28d	8	20	--	--	--
56 cm diam. spot - fert.	100a	88	12	62bc	14	38	--	--	--
1.2 m strip - fert.	94a	88	6	32cd	16	16	46c	22	24

* Condition is expressed as a percentage of spruce seedlings assigned to each Condition Category. 0 - 1: healthy - good and 2 - 3: fair - poor.

** Percentages followed by the same letter are not significantly different at the 5% level using Duncan's Multiple Range Test (Duncan, 1955).

TABLE 13 Height* and Dry Weight** of Lodgepole Pine Seedlings After Various Treatments - Experiments Cld, e and f.

	Mayberne (Cld.)		Stony Plain (Cle.)			Grande Prairie (Clf.)		
	Height		Height		Weight	Height		Weight
Treatments	3 mos.	14 mos.	3 mos.	14 mos.	14 mos.	3 mos.	14 mos.	14 mos.
Control	100b-d*** (13.3 cm)	100b-d (18.4cm)	100b (8.7cm)	100ab (10.1 cm)	100c (3.8 gm)	100ab (8.2cm)	100bc (10.0 cm)	100bc (2.8 gm)
Scalp	104bc	97b-d	102ab	114a	149b	99ab	115b	144b
Glyphosate 4.5 kg/ha:								
28 cm diam. spot	102bc	94cd	26e	21c	12e	--	--	--
56 cm diam. spot	107ab	90d	41de	27c	17e	--	--	--
1.2 m strip	92d	98b-d	53cd	34c	28de	84b	74cd	79c
Control - fert.	97cd	109a-c	100b	80b	76cd	105a	100bc	89c
Scalp - fert.	114a	118a	119a	122a	197a	116a	147a	204a
Glyphosate 4.5 kg/ha:								
28 cm diam. spot - fert.	105bc	93cd	41de	29c	37e	--	--	--
56 cm diam. spot - fert.	103bc	112ab	67c	48c	50c-e	--	--	--
1.2 m strip - fert.	107ab	120a	45de	34c	51c-e	55c	48d	53c

* Height is expressed as a percentage calculated from the mean height per pine seedling per treatment.

** Dry weight is expressed as a percentage calculated from the mean dry weight per replicate per treatment.

*** Percentages followed by the same letter are not significantly different at the 5% level using Duncan's Multiple Range Test (Duncan, 1955).

Survival and Condition

Percentage survival was significantly greater in all plots not receiving glyphosate compared with plots receiving glyphosate except for the 56 cm spot plus fertilizer treatment. Percentage survival of pine in the non-glyphosate plots ranged from 74 to 88% while percentage survival of pine in glyphosate plots ranged from 22 to 62% (Table 12). Forty-two to 74% of pine seedlings planted in non-glyphosate treated plots were assigned to the condition category 0-1 (healthy-good) while only 6 to 16% of pine seedlings in the glyphosate treated plots were assigned to the same condition category. The condition of the majority of pine seedlings in the glyphosate treatment was therefore "fair" to "poor".

Height Growth

The mean height of pine, 3 months after treatment, was significantly less in all glyphosate treatments compared with the plots not receiving glyphosate (Table 13). The pine seedlings in the fertilized scalps were significantly taller than pine in both the fertilized and unfertilized control and apparently (although not significantly) greater than the unfertilized scalps. Height of pine in the fertilized scalp treatment was 19% greater than the control.

Fourteen months after treatment the mean height of pine seedlings in all glyphosate treated plots was again significantly less than the mean height of pine in all non-glyphosate treatments. Fertilized and unfertilized pine in the scalps had a significantly greater mean height than pine in the fertilized control, but height of pine in the scalps was not significantly greater than unfertilized pine in the control plot. Although not a statistically significant increase, pine in the fertilized scalps attained a height apparently 22% greater than the control while pine in unfertilized scalps seemed to have less improvement over the controls.

Weight

Fourteen months after the treatment, the pine planted in both fertilized and unfertilized scalp treatments achieved a mean weight per replicate significantly greater than the mean weight of pine in all other treatments (Table 13). Pine in the fertilized scalps weighed significantly more than pine in the unfertilized scalps. The pine in the fertilized scalps weighed almost twice as much as the unscalped, unfertilized, controls whereas pine in the unfertilized scalps weighed approximately 50% more than pine in the same control.

Clf. Lodgepole Pine at Grande Prairie

Herbaceous Vegetation Control

Weed control in the various plots was fair or poor 14 months after treatment, similar to that noted for experiment Clc (Table 9).

Survival and Condition

The percentage survival of pine in fertilized and unfertilized scalps was significantly higher than for pine in either glyphosate treated strip. Eighty and 74% of the pine in fertilized and unfertilized scalps, respectively were classified in the 0-1 (healthy-good) category whereas the percentage of pine seedlings in other treatments assigned to the same condition category ranged from only 22 to 58 (Table 12).

Height Growth

After 3 months the mean heights of pine seedlings in the fertilized control and fertilized scalps appeared to be 5 and 16% greater, respectively. than the unfertilized control and were significantly higher than fertilized and unfertilized pine in the glyphosate treated strip (Table 13). The fertilized pine in both the control and scalp achieved an apparently, but not significantly, greater height than the unfertilized pine in similar treatments.

The mean height of pine in fertilized scalps was significantly greater than the mean height of pine in all other treatments 14 months after treatment. Pine in this treatment was 47% taller than the pine in the unfertilized control. In addition pine in the unfertilized scalps grew significantly taller than pine in the glyphosate treated strips.

Weight

The weights of pine seedlings indicate a trend similar to that of their height (Table 13). Weights in fertilized scalps were superior to those for any other treatment.

C2. Effects of Late Summer Treatments on Competing Vegetation and Survival and Growth of Lodgepole Pine with and without Scalps (1976)

C2a. and b. Mayberne and Stony Plain

Herbaceous Vegetation Control

Vegetation control in the glyphosate treated strips at Mayberne and Stony Plain was initially excellent and 12 months later remained "good" (75 to 99%) (Plate 4) (Table 14). Reinvasion in the scalps, however, appeared to be more rapid than in the strips. After the same period of time, 25 to 50% reinvasion of grasses and forbs had occurred in the scalps ("fair" control).

Survival and Condition

At Mayberne and Stony Plain, percentage survival of pine was significantly less in the glyphosate treated strips than in the scalp and control treatments. At Stony Plain only 11% of the pine seedlings survived compared to 99 and 93% survival of pine in the scalp and control treatment respectively (Table 15). At Mayberne 3 times as many surviving pine seedlings were assigned to the 2-3 (fair-poor) condition category than were assigned to the 1-0 (healthy-good) condition category.

Survival of pine in the scalps and control at both experimental locations, 12 months after treatment, was excellent. At Mayberne 20% more pine seedlings were assigned to the 0-1 condition category in the scalps compared with the control treatment. Similarily at Stony Plain 16% more pine seedlings were assigned to the same condition category in scalp treatments compared with the controls.

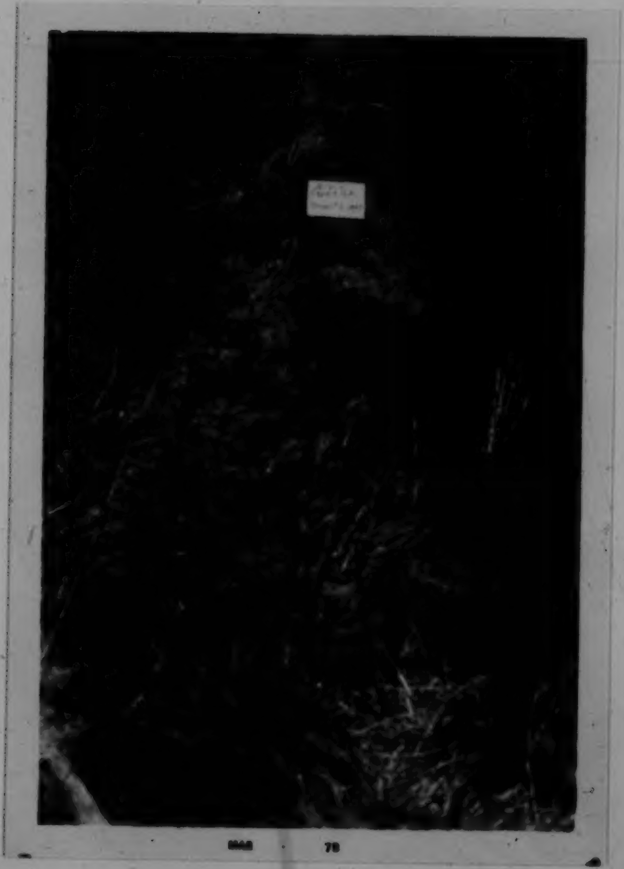

Plate 4 Vegetation Reinvasion at Mayberne (C2a) 12 Months After Late Summer Treatment With Glyphosate at 4.5 kg/ha. Compare with Plate 1.

TABLE 14 Effectiveness* of Vegetation Control by 1976 Late Summer Glyphosate Treatments (C2a and b); by Scalps with and without Glyphosate Treatments (C3a and b), and by 1977 Spring Glyphosate Treatments (C4a, b and c)

	12 mos. after 1 Aug. 1976 Treatment		1977 Scalps 2.5 mos. after Treatment		1977 Spring Treatments 2.5 mos. after Treatment		
Treatments	C2a. (Mayberne)	C2b. (Stony Plain)	C3a. (Stony Plain)	C3b. (Pass Creek)	C4a. (Stony Plain)	C4b. (Stony Plain)	C4c. (Pass Creek)
Control	0	0	0	0	0	0	0
Scalps	2	2	3	3	-	-	-
Scalps in Gly. Strips	-	-	2	3-	-	-	-
Strips - Gly. 4.5 kg/ha	3	3-	3	2+	3	3	3-

* 0 - very poor: 0 to 25% control
1 - poor: 25 to 50% control
2 - fair: 50 to 75% control
3 - good: 75 to 99% control
4 - excellent: 100% control

TABLE 15 Effects of Late Summer Treatments on Survival, Condition*, Height** and Dry Weight*** of Lodgepole Pine Seedlings After 12 months - Experiments C2a and b. (mean of 3 replications)

	Mayberne (C2a.)				Stony Plain (C2b.)				
		Condition Category				Condition Category			
Treatments	% Survival	0-1	2-3	Height	% Survival	0-1	2-3	Height	Weight
Control	94a****	70	26	100a (10.3cm)	93a	62	31	100b (11.9cm)	100b (59.5gms)
Scalp	100a	90	10	98a	99a	79	20	120a	137a
Strip (Gly - 4.5 kg/ha)	67b	18	54	60b	11b	6	5	9c	13c

* Condition is expressed as a percentage of pine seedlings assigned to each Condition Category.

** Height is expressed as a percentage calculated from the mean height per pine seedling per treatment.

*** Dry weight is expressed as a percentage calculated from the mean dry weight per replicate per treatment.

**** Percentages followed by the same letter are not significantly different at the 5% level using Duncan's Multiple Range Test (Duncan, 1955).

Height and Weight

Twelve months following treatment at Mayberne, the mean height of pine in the glyphosate treated strip was significantly less than the same measurements for pine in the control or scalp treatment. The heights attained by pine in the control and scalp treatments were nearly equal.

After a similar period of time at Stony Plain, severe damage resulted to pine in the glyphosate treated strip. The mean height of pine in this treatment was 91% less than the mean height of pine in the control and the mean weight of pine was 87% less than the control (Table 14).

The mean height and mean weight of pine seedlings in the scalps at Stony Plain were significantly greater than the corresponding measurements of pine in the control treatments.

C3. Vegetation Control in Scalps with and without Treatment

C3a. and b. Stony Plain and Pass Creek

Percentage vegetation control in the glyphosate treated strips, after 2.5 months, at Stony Plain, was 80 to 90 while percentage control in the same treatment at Pass Creek was 65 to 75 (Table 14). At Stony Plain and Pass Creek, scalps not receiving glyphosate treatments had vegetation control ranging from 80 to 90% while scalps receiving glyphosate treatments had a lower control rating (60 - 80%). It was noted at both locations that broad-leaved plants appeared to increase in density in scalps when the surrounding vegetation had been killed by glyphosate.

C4. Effects of Spring Treatments on the Survival, Condition and Growth of Lodgepole Pine Seedlings (1977)

C4a. Stony Plain, C4b. Stony Plain - Delayed Planting and C4c. Pass Creek

Herbaceous Vegetation Control

Initial vegetation control with glyphosate at all three experimental sites was excellent. After 2.5 months "good" (75 to 90%) vegetation control existed (Table 14).

Survival and Condition

Survival of pine seedlings in the control plots was excellent in all 3 experiments (C4a, b and c); ranging from 90 to 99%. The condition of nearly 100% of the surviving control seedlings in the 2 experiments at Stony Plain was 2-3 (fair-poor). At Pass Creek, over half of the surviving control seedlings were assigned to the 2-3 (fair-poor) condition category with the remainder being assigned to the 0-1 (healthy-good) condition category.

After 2.5 months, survival of pine seedlings in glyphosate treated strips was drastically reduced in experiment C4c (Pass Creek), in which spraying preceded planting by 3 hours (Table 16). Only 7% of the pine seedlings survived.

At Stony Plain, where spraying had preceded planting by one day, survival of pine seedlings in glyphosate treated plots was reduced by 33% compared with the control. Survival of pine seedlings planted 6 days after spraying in similar plots at Stony Plain was only slightly reduced

TABLE 16 Effects of 1977 Spring Glyphosate Treatments on Survival and Condition* of Lodgepole Pine Seedlings After 2.5 Months - Experiments C4a, b and c (Mean of 3 replications)

Treatments	Stony Plain (C4a.)			Stony Plain - Delayed Planting (C4b.)			Pass Creek (C4c.)		
	% Survival	Condition Category		% Survival	Condition Category		% Survival	Condition Category	
		0-1	2-3		0-1	2-3		0-1	2-3
Control	99	2	97	90	0	90	90	35	55
Strip - Gly. 4.5 kg/ha	65	2	63	82	2	80	7	0	7

* Condition is expressed as percentage of spruce seedlings assigned to each condition category. 0-1: health-good and 2-3: fair-poor.

compared with the number of pine seedlings surviving in the control.

The condition of the surviving pine in the glyphosate and control plots in all 3 experiments was generally fair to poor (2-3 condition category).

Leader Lengths and Weight

Total growth (as measured by leader length) of pine seedling in the glyphosate treatment at Pass Creek was nearly 100% less than growth of pine in the control, 2.5 months after treatment (Table 17). After a similar length of time, the mean leader length and mean weight of pine in experiment C4a. (Stony Plain - pine planted 1 day after spray) was significantly less in the glyphosate treated plots compared with pine in the controls. In experiment C4b. (Stony Plain - pine planted 6 days after spraying) there was no significant difference in mean leader length and mean weight of pine between the glyphosate treatment and the control.

C5. Comparison of Different Rates of Application on Competing Vegetation and on Lodgepole Pine (1976 and 1977)

C5a and b. Mayberne and Stony Plain - Pine Planted 10 Months After Spraying

Herbaceous Vegetation Control

Vegetation control in 1977, 12 months after spraying at Mayberne (C5a.) was "good" (80 to 90%) in the 2.2 to 5.6 kg/ha plots. Control in the 1.1 kg/ha plots was rated as "fair" (65 to 75%) after the same length of time. Plate 5

TABLE 17 Effects of 1977 Spring Glyphosate Treatments on Leader Length* and Dry Weight** of Lodgepole Pine Seedlings after 2.5 Months - Experiments C4a, b and c (Mean of 3 replications)

	Stony Plain (C4a.)		Stony Plain - Delayed Planting (C4b.)		Pass Creek (C4c.)
Treatments	Leader Length	Dry Weight	Leader Length	Dry Weight	Leader Length
Control	100a*** (1.7cm)	100a (3.3gms)	100a (2.1cm)	100a (3.4gms)	100 (1.5cm)
Strip - Gly. 4.5 kg/ha	66b	68b	87b	93a	0.4

* Leader Length is expressed as a percentage calculated from the mean leader length per pine seedling per treatment.

** Dry Weight is expressed as a percentage calculated from the mean dry weight per replicate per treatment.

*** Percentages followed by the same letter are not significantly different at the 5% level using Duncan's Multiple Range Test (Duncan, 1955).

Plate 5 Vegetation Control at Mayberne (C5a) 10 Months After Late Summer Applications of Glyphosate at 1.1 (Right) and 5.6 (Left) kg/ha

provides a comparison of the 1.1 kg/ha plot with the 5.6 kg/ha plot 10 months after glyphosate treatment at Mayberne.

Vegetation reinvasion at Stony Plain (C5b) after 12 months was more pronounced than at Mayberne. Control in the plots receiving from 2.2 to 5.6 kg/ha was fair (60 to 70%) while control in the plots receiving 1.1 kg/ha was "poor" (30 to 40%).

Survival and Condition

Three months after planting in 1977 the survival of pine seedlings at Mayberne (C5a) and Stony Plain (C5b) was very good in the control plots and in plots sprayed with glyphosate in 1976; 10 months prior to planting (Table 18). At Mayberne the majority of surviving pine were assigned to the 0-1 (healthy-good) condition category while all surviving pine at Stony Plain were assigned to the 2-3 (fair-poor) condition category.

Leader Length and Weight

Three months after planting at Mayberne in 1977, (C5a) and Stony Plain (C5b) the mean leader length and mean weight of pine seedlings in the 1976 glyphosate treated strips were not significantly different from the corresponding control (Table 19). The mean weight of pine seedlings at Stony Plain (C5b) was at least as great in the glyphosate treated plot as it was in the control.

C5c. Stony Plain - Planted Immediately After Spraying (1977)

Herbaceous Vegetation Control

After 2.5 months vegetation control ratings for glyphosate dosages ranging from 1.1 to 5.6 kg/ha in plots at this site were similar to the ratings in the respective plots at Mayberne (C5a) 12 months after spraying.

Survival and Condition

A drastic decrease in percentage survival was evident in all plots receiving glyphosate treatment from 1.1 to 5.6 kg/ha, compared with the control. Survival in the control was 95% whereas survival in the glyphosate treated plots ranged from 5 to 45% (Table 18). The condition category to which the majority of pine seedlings in all plots, including the control, were assigned was 2-3 (fair-poor).

Leader Length and Weight

The mean length of the leader and mean weight of pine seedlings in all plots sprayed with glyphosate were significantly less than the mean of the same measurements of pine seedlings in the control (Table 19).

C5d. Economy - Planted 1 Year Previous to Spraying

Herbaceous Vegetation Control

Vegetation control was "good" (75 to 85%) 12 months after spraying at all dosage rates from 1.1 to 5.6 kg/ha. Grass control was excellent, however a moderate infestation of fireweed, sticky willow herb (*Epilobium glandulosum* Lehm.) and other broadleaved plants had occurred in the plots.

TABLE 18 Effects of Various Dosages of Glyphosate on Survival and Condition* of Lodgepole Pine Seedlings Planted 10 Months (C5a and b) or Immediately After Spraying (C5c). Data Recorded 3 Months (C5a and b) or 2 Months (C5c) After Planting

	Planted 10 Months After 1976 Spraying						Planted Immediately After 1977 Spraying		
	Mayberne (C5a.)			Stony Plain (C5b.)			Stony Plain (C5c.)		
Dosage kg/ha	Condition Category		% Survival	Condition Category		% Survival	Condition Category		% Survival
	0-1	2-3		0-1	2-3		0-1	2-3	
0.0	75	23	98	0	92	92	0	95	95
1.1	--	--	--	--	--	--	0	35	35
2.2	--	--	--	--	--	--	5	30	35
3.4	--	--	--	--	--	--	5	40	45
4.5	88	12	100	0	78	78	0	5	5
5.6	--	--	--	--	--	--	0	25	25

* Condition is expressed as a percentage of pine seedlings assigned to each condition category: 0-1: healthy-good and 2-3: fair-poor.

TABLE 19 Effects of Various Dosages of Glyphosate on Leader Length* and Dry Weight** of Lodgepole Pine Seedlings Planted 10 Months After (C5a and b) or Immediately After Spraying (C5c.) Data Recorded 3 Months (C5a and b) or 2 Months (C5c.) After Planting

	Planted 10 Months After Spraying			Planted Immediately After Spraying	
Dosage kg/ha	Mayberne (C5a.)	Stony Plain (C5b.)		Stony Plain (C5c.)	
	Leader Length	Leader Length	Dry Weight	Leader Length	Dry Weight
0.0	100a (4.6cm)	100a (2.0cm)	100a (3.5gms)	100a*** (2.8cm)	100a (1.9gms)
1.1	--	--	--	33bc	24bc
2.2	--	--	--	36b	27bc
3.4	--	--	--	41b	32b
4.5	99a	99a	127a	4d	1e
5.6	--	--	--	13cd	11cd

* Leader Length is expressed as a percentage calculated from the mean leader length per pine seedling per treatment.

** Dry Weight is expressed as a percentage calculated from the mean dry weight per replicate per treatment.

*** Percentages followed by the same letter are not significantly different at the 5% level using Duncan's Multiple Range Test (Duncan, 1955).

Survival and Condition

All 19 of the 4 year old pines that were included within the plots had survived. Seventy-nine percent of these trees were assigned to the "healthy" condition category. Tip damage on the terminal leader was noted on 3 plants.

Of the pines located in the untreated grass adjacent to the plots, 77% were assigned to the "healthy" condition category.

Leader Length

The mean leader length of 19 pines growing within the plots was 18.5 cm whereas the corresponding mean for 13 pine, in grass adjacent to the plots was 19.3 cm.

C6. Effects on Lodgepole Pine in Greenhouse and Growth Chamber Experiments at Edmonton

C6a. Effects on Pregerminated Lodgepole Pine Seed

In the preliminary trial (using medium sand and 1:1:1 greenhouse soil) the survival and height of pine seedlings in flats treated with glyphosate tended to be less than survival and height of pine seedlings planted in the control flat. However, in the trial using 1:1:1 soil these reductions in survival and height were not significant. In the trial using medium sand the mean height of pine in flats receiving 2.2 and 4.5 kg/ha. of glyphosate was significantly less than the mean height of pine in the control flat.

In the second trial, using 1:1:2 soil, the glyphosate dosages from 2.2 to 9.0 kg/ha resulted in mean heights and mean fresh weights of pine significantly less than the corresponding means of pine in the control (Table 20).

C6b. Effects on Germination and Growth of Lodgepole Pine - Not Pregerminated

In a preliminary set of experiments the percentage germination, mean height and mean fresh weight of pine were not significantly different in the glyphosate treatments of 2.2 and 4.5 kg/ha compared with the corresponding measurements of pine in the control. A second set of experiments produced results similar to those of the preliminary experiments (Table 21).

C6c. Effects on Lodgepole Pine Seedlings Planted in Different Soils After Spraying the Soil

After 3.5 months for the first experiment and 1.5 months for the second experiment in the greenhouse, the results indicated that dry weights (first experiment) and growth (second experiment) of pine in pots receiving rates of application of glyphosate higher than 2.2 kg/ha were considerably less than they were in the control, with the exclusion of Mayberne soil in which no damage from glyphosate treatment occurred (Table 22). In the first experiment the dry weight of pine planted in Stony Plain soil receiving any dosage of glyphosate from 1.1 to 9.0 kg/ha was significantly less than the dry weights of pine in the control. A similar trend is apparent in Stony Plain soil in the second experiment. However, growth of pine was significantly less than the control only in pots receiving 4.5 and 6.7 kg/ha of glyphosate.

TABLE 20 Effects of Various Dosages of Glyphosate on Survival, Height* and Fresh Weight** of Seedlings from Pregerminated Lodgepole Pine Seed after 50 Days in the Growth Chamber - Experiment C6a. (mean of 3 replicates).

Dosages kg/ha	% Survival	Height	Fresh Weight
0.0	85a***	100a (2.9cm)	100a (2.4gms)
2.2	37ab	43b	45b
4.5	20b	22b	23b
6.7	23b	24b	20b
9.0	40ab	32b	25b

* Height is expressed as a percentage calculated from the mean height per pine seedling per treatment.

** Fresh weight is expressed as a percentage calculated from the mean fresh weight per replicate per treatment.

*** Percentages followed by the same letter are not significantly different at the 5% level using Duncan's Multiple Range Test (Duncan, 1955).

TABLE 21 Effects of Various Dosages of Glyphosate on Germination, Height* and Fresh Weight** of Lodgepole Pine in the Growth Chamber 50 Days after Treatment - Experiment C6b. (means of 6 replications).

Dosages kg/ha	% Germination	Height	Fresh Weight
0.0	38ab***	100a (1.0cm)	100a (0.6gms)
2.2	33ab	80a	81a
4.5	27b	63a	56a
6.7	40ab	97a	89a
9.0	46a	108a	103a

* Height is expressed as a percentage calculated from the mean height per pine seedling per treatment.

** Fresh weight is expressed as a percentage calculated from the mean fresh weight per replicate per treatment.

*** Percentages followed by the same letter are not significantly different at the 5% level using Duncan's Multiple Range Test (Duncan, 1955).

TABLE 22 Effects on Dry Weight* and Growth** of Lodgepole Pine Seedlings of Various Dosages of Glyphosate on Different Soil Types - Experiment C6c.

Treatments kg/ha	First Experiment - 106 Days (Dry Weight)					Second Experiment - 45 Days (Growth)		
	Mayberne	Pass Creek	Stony Plain	1:1:2	3:1:1	Stony Plain	1:1:2	3:1:1
0.0	100a*** (2.8gms)	100a (2.9gms)	100a (2.6gms)	100a (4.7gms)	100a (3.9gms)	100a (2.1cm)	100a (3.8cm)	100a (4.5cm)
1.1	--	--	--	--	--	53ab	77ab	70ab
2.2	94a	96a	53b	70a	69a	70ab	41bc	86a
4.5	80a	98a	34b	60ab	26b	20b	32bc	32bc
6.7	105a	71ab	17b	48b	21b	7b	22c	10c
9.0	114a	38b	19b	49b	19b	--	--	--

* Dry weight is expressed as a percentage calculated from the mean dry weight per pine seedling per treatment.

** Growth is expressed as a percentage calculated from the mean growth per replicate per treatment.

*** Percentages followed by the same letter are not significantly different at the 5% level using Duncan's Multiple Range Test (Duncan, 1955).

The dry weight (first experiment) and growth (second experiment) of pine in the two greenhouse soil mixtures (1:1:2 and 3:1:1) sprayed at rates of application higher than 2.2 kg/ha were significantly less than those of their controls.

Pine survival, condition ratings and growth data (first experiment) which are not included in Table 22 indicated similar trends, supporting the data in Table 22.

Unexpected growth of sedges occurred in the pots with Mayberne soil. The density of growth of the sedges apparently increased with decreasing dosages of glyphosate (Plate 6), therefore indicating some residual effect of the chemical treatment on sedge seed germination.

The growth of pine seedlings in Stony Plain soil and the 3:1:1 greenhouse soil mixture for 45 days after treatments is shown in Figures 1 and 2.

Plate 6 illustrates the damage to pine at all rates of glyphosate in the Stony Plain soil and the apparent lack of similar damage to pines in the Mayberne soil 8 weeks after treatment.

C6d. Survival and Growth of Lodgepole Pine Seedlings Under Treated and Sprinkled Grass

Eighty-six days after placing pine seedlings under treated and sprinkled grass, there was no significant difference in survival, height or dry weight of these seedlings compared with seedlings in the control flats (Table 23).

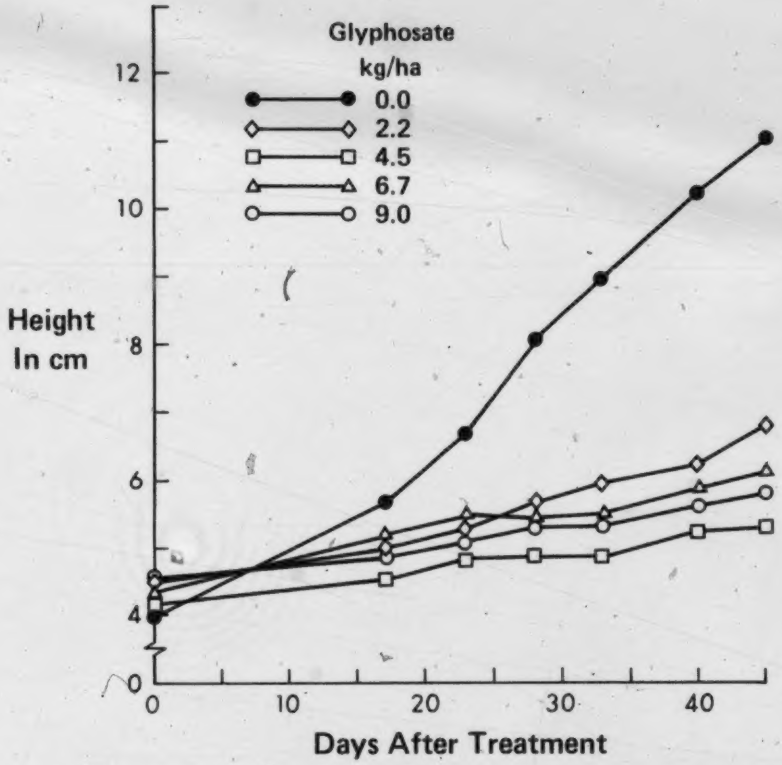

Figure 1 Effects of Various Dosages of Glyphosate on Growth of Lodgepole Pine Seedlings in the Greenhouse in Stony Plain Soil Sprayed 1 Day Before Planting

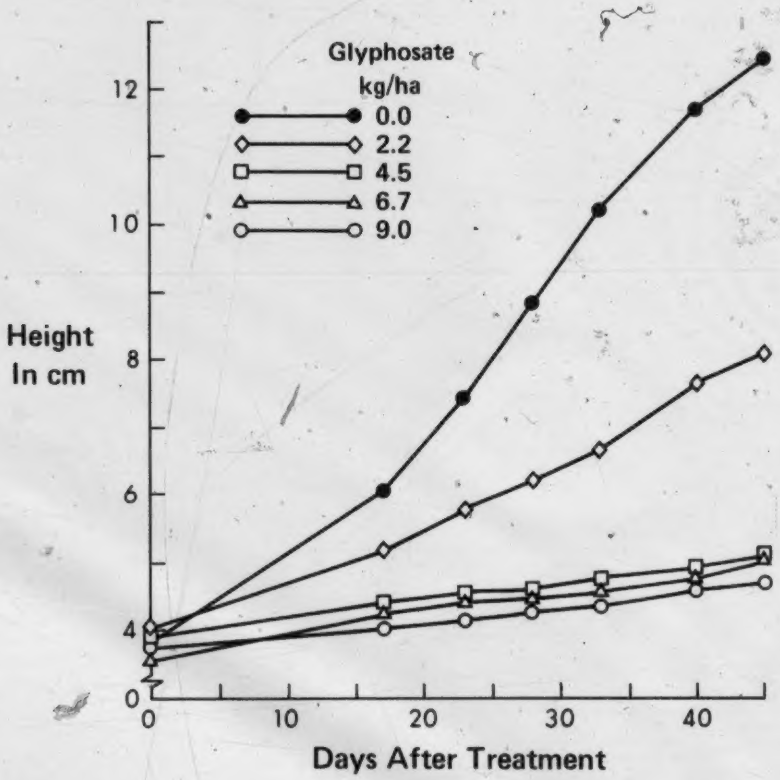

Figure 2 Effects of Various Dosages of Glyphosate on Growth of Lodgepole Pine Seedlings in the Greenhouse in 3:1:1 Soil Sprayed 1 Day Before Planting

8 weeks after
pre-plant soil
trtmt Glyphosate
0, 2, 4, 6, 8 lb/A
0
0
2
4
2
6
8
6
8

Plate 6 Effects, 2 Months After Application of 0.0(0), 2.2 (2), 4.5 (4), 6.7 (6) and 9.0 (8) kg/ha (lb/A) of Glyphosate, on Condition of Lodgepole Pine Seedlings in the Greenhouse in Mayberne (Edson-left) and Stony Plain (Dog Lake-right) Soil Sprayed 1 Day Before Planting (C6c)

TABLE 23 Survival, Height* and Dry Weight** of Lodgepole Pine Seedlings After 86 Days Under or in Contact With Water-Sprinkled, Glyphosate-Treated, Wheat Leaves (means of 2 replications)

Dosage kg/ha	(lb/A)	Seedlings Under Suspended Treated Leaves (C6d.) % Survival	Height	Weight	Seedlings in Contact With Treated Leaves (C6e.) % Survival	Height	Weight
0.0	(0)	92a***	100a (5.0cm)	100a (2.1gms)	94a	100a (6.6cm)	100a (5.4gms)
4.5	(4)	98a	117a	114a	100a	94a	99a
9.0	(8)	98a	108a	102a	50b	47b	28b

* Height is expressed as a percentage calculated from the mean height per pine seedling per treatment.

** Dry weight is expressed as a percentage calculated from the mean dry weight per replicate per treatment.

*** Percentages followed by the same letter are not significantly different at the 5% level using Duncan's Multiple Range Test (Duncan, 1955).

C6e. Survival and Growth of Lodgepole Pine Seedlings in Contact with Treated and Sprinkled Grass

The percentages survival, height and dry weight of pine seedlings in contact with grass leaves treated with 9.0 kg/ha of glyphosate a day before placement among the seedlings were significantly less than the percentage survival, height and dry weight of pine in contact with grass treated with 0.0 and 4.5 kg/ha of glyphosate (Table 23).

C7. Tolerance of Conifers to Direct Treatments

C7a. Lodgepole Pine in the Greenhouse

Seven months after treatment, mortality of pine seedlings initially receiving 6.7 kg/ha of glyphosate was 40% compared to pine in the control in which 10% mortality occurred (Table 24). After the same length of time glyphosate-treated pine seedlings were assigned equally to the 0-1 (healthy-good) and the 2-3 (fair-poor) condition category whereas the majority of untreated pine seedlings were assigned to the 0-1 (healthy-good) condition category.

C7b. White Spruce and Lodgepole Pine in the Field at Ellerslie

Herbaceous Vegetation Control

Initial control of grasses was excellent and control after 2 months remained "good" (75 to 99%) in all glyphosate treated plots.

Survival and Condition

In this field experiment at Ellerslie, 2 months after over-the-top spraying of glyphosate, 50% of spruce

TABLE 24 Effects of Direct Treatment on Survival and Condition* of Lodgepole Pine Seedlings After 7 Months in the Greenhouse - Experiment C7a

Treatment kg/ha	% Survival	Condition Category	
		0-1	2-3
0.0	90	80	10
1.1	90	60	30
3.4	80	40	40
6.7	60	30	30

*Condition is expressed as a percentage of pine seedlings assigned to each condition category. 0-1: healthy-good and 2-3: fair-poor.

and pine had been killed by the 6.7 kg/ha rate (Table 25). Survival of spruce and pine tended to decrease with increasing dosages of glyphosate. In addition, the condition category to which the majority of sprayed spruce and pine seedlings were assigned was 2-3 (fair-poor). On the other hand the majority of the unsprayed seedlings were in the 0-1 (healthy-good) condition category.

Height Growth

The mean height of spruce and pine sprayed with 4.5 and 6.7 kg/ha of glyphosate ranged from 58 to 64% less than the mean height of unsprayed spruce or pine.

C8. Effects of Treatments on Survival and Growth of Newly Planted Deciduous Species

C8a. Willow at Stony Plain

Herbaceous Vegetation Control

Vegetation control was poor 14 months after treatment similar to that noted for experiments Clb and e.

Survival and Weight

There was no significant difference between percentage survival of willows in controls and treated plots (Table 26). The mean dry weight of willows in scalps and the 1.2 m glyphosate treated strip was significantly greater than the mean dry weight of willows in the control treatments.

C8b. Willow at Grande Prairie

Herbaceous Vegetation Control

Vegetation control was fair to poor 14 months after treatment similar to that noted for experiment Clc and Clf.

TABLE 25 Effects of Direct Spray Treatment with Glyphosate on Survival, Condition* and Height** of White Spruce and Lodgepole Pine Seedlings in the Field (Ellerslie) After 2 Months - Experiment C7b.

Treatment kg/ha	Spruce % Survival	Spruce Condition Category 0-1	Spruce Condition Category 2-3	Spruce Height	Pine % Survival	Pine Condition Category 0-1	Pine Condition Category 2-3	Pine Height
0.0	100	60	40	100 (10.8cm)	90	90	0	100 (5.4cm)
2.2	90	30	60	58	80	10	70	91
4.5	50	10	40	37	60	10	50	36
6.7	50	10	40	37	50	10	40	42

* Condition is expressed as a percentage of conifer seedlings assigned to each condition category. 0-1: healthy-good and 2-3: fair-poor.

** Height is expressed as a percentage calculated from the mean height per conifer seedling per treatment.

TABLE 26 Effects of Glyphosate Treatment on Survival and Dry Weight* of Willow - Experiments C8a and b.

	Stony Plain (13 mos.)		Grande Prairie (14 mos.)	
Treatment	% Survival	Weight	% Survival	Weight
Control	86a**	100b (4.3gms)	86a	100bc (40.0gms)
Scalp	94a	160a	58b	78bc
Glyphosate 4.5 kg/ha:				
28 cm spot	78a	99b	24c	17c
1.2 m strip	92a	158a	84a	200a
0.6 m strip	82a	128ab	78ab	180ab

* Dry weight is expressed as a percentage calculated from the mean dry weight per willow per treatment.

** Percentages followed by the same letter are not significantly different at the 5% level using Duncan's Multiple Range Test (Duncan, 1955).

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Survival and Weight

In contrast to the similar experiment at Stony Plain (C8a) the percentage survival of willows in the scalp and glyphosate treated spots was significantly less than the percentage survival of willows in the control (Table 26). Survival of willows in the two glyphosate treated strips was not significantly different from the control.

The dry weight of willows in the 1.2 m strip was significantly greater than dry weight of willows in any other treatment.

C8c. Caragana at Stony Plain

Herbaceous Vegetation Control

Vegetation control was good 2.5 months after treatment similar to that noted for experiments C4a and b.

Survival and Weight

No significant differences in percentage survival or weight of survivors were found between treatments (Table 27).

C8d. Caragana at Grande Prairie

Herbaceous Vegetation Control

Vegetation control in all glyphosate treated plots was "good" (80 to 90%) 2.5 months after treatment.

Survival and Weight

No significant differences were found between treatments (Table 27).

TABLE 27 Effects of Glyphosate Treatment on Survival and Fresh Weight* of Caragana After 2.5 Months - Experiment C8c and d.

	Stony Plain		Grande Prairie	
Treatment	% Survival	Weight	% Survival	Weight
Control	71a**	100a (116.8gms)	73a	100a (8.9gms)
Glyphosate 4.5 kg/ha				
1.2 m strip	56a	123a	34a	48a

* Fresh weight is expressed as a percentage calculated from the mean fresh weight per replicate per treatment.

** Percentages followed by the same letter are not significantly different at the 5% level using Duncan's Multiple Range Test (Duncan, 1955).

D. Soil Treatments

D1. Effects of Herbicides and Scalping on Competing Vegetation and on Survival, Condition and Growth of White Spruce and Lodgepole Pine

D1a. Simazine and Karbutilate at Mayberne

Herbaceous Vegetation Control

After 2 months 90% control of grasses and broad-leaved plants occurred in the plots receiving 15.7 kg/ha of karbutilate and 60 to 80% control occurred in plots sprayed with 7.8 kg/ha of karbutilate. Vegetation did not appear to be affected in plots treated with 15.7 or 31.4 kg/ha of simazine. Little or no reinvasion of grasses had occurred in the scalps.

In the spring of 1977, 10 months after treatment, control was 70 and 80% in the 7.8 and 15.7 kg/ha dosages of karbutilate, respectively. Grass control in the 15.7 and 31.4 kg/ha plots of simazine was poor.

Fourteen months after treatment, control was "good" (75 to 99%) in the 7.8 and 15.7 kg/ha rates of karbutilate (Table 28). Vegetation control in the 31.4 kg/ha rate of simazine was "fair" (60 to 70%) while control in the 15.7 kg/ha rate was "poor" (40 to 50%). Twenty-five to 50% vegetation reinvasion of the scalps had occurred after the same length of time.

Survival and Condition - Spruce

After 14 months the only significant differences in survival of spruce seedlings had resulted from both rates

TABLE 28 Effectiveness* of Soil Treatments on Control of Vegetation 14 Months (Dla.) and 11.5 Months (Dlb.) After Treatment

		Dosages kg/ha							
		Simazine		Karbutilate		Velpar			
Experiment	Scalp	15.7	31.4	7.8	15.7	2.2	3.4	4.5	5.6
Mayberne (Dla)	2	1+	2	3-	3+	--	--	--	--
Grande Prairie (Dlb)	--	--	--	--	--	3	3	3	3

* 0 - very poor: 0 to 25% control
1 - poor: 25 to 50% control
2 - fair: 50 to 75% control
3 - good: 75 to 99% control
4 - excellent: 100% control

of karbutilate, which increased spruce mortality (Table 29). The majority of spruce seedlings were assigned to the 0-1 (healthy-good) condition category except in the plot with 15.8 kg/ha of karbutilate where the majority of spruce seedlings were in the 2-3 (fair-poor) condition category.

Survival and Condition - Pine

Data for survival and condition of pine seedlings were similar to those for spruce seedlings.

Height Growth - Spruce

No significant differences in height of spruce seedlings occurred between treatments after 14 months except that the mean height of seedlings in the 15.7 kg/ha dosage of simazine was significantly greater than the mean height of seedlings in both dosages of karbutilate (Table 29). The height of spruce in karbutilate treatments was less than the height of spruce in any other treatment.

Height Growth - Pine

The mean heights of pine seedlings in both dosages of karbutilate were significantly less than the mean height of pine seedlings in all other treatments.

D1b. Velpar at Grande Prairie

Herbaceous Vegetation Control

After 11.5 months vegetation control in all Velpar plots (2.2 to 5.6 kg/ha) was "good" (80 to 90%)(Table 28).

TABLE 29 Comparisons of Scalping, Simazine and Karbutilate on Survival, Condition* and Height** of White Spruce and Lodgepole Pine Seedlings 14 Months After Treatment at Mayberne - Experiment Dla. (means of 3 replicates)

	Spruce				Pine			
	% Survival	Condition Category		Height	% Survival	Condition Category		Height
Treatments		0-1	2-3			0-1	2-3	
Control	82a***	78	4	100ab (8.9cm)	83a	80	3	100a (16.7cm)
Scalp	82a	82	0	98ab	85a	80	5	108a
Simazine:								
15.7 kg/ha	78a	72	6	109a	73ab	65	8	108a
31.4 kg/ha	78a	63	15	94ab	82a	77	5	100a
Karbutilate:								
7.8 kg/ha	53b	35	18	76b	60b	42	18	69b
15.8 kg/ha	23c	3	20	76b	30c	12	18	64b

* Condition is expressed as a percentage of conifer seedlings assigned to each condition category. 0-1: healthy-good and 2-3: fair-poor.

** Height is expressed as a percentage calculated from the mean height per conifer seedling per treatment.

*** Percentages followed by the same letter are not significantly different at the 5% level using Duncan's Multiple Range Test (Duncan, 1955).

Survival and Condition - Spruce

Survival of spruce seedlings in the 5.6 kg/ha rate of Velpar was significantly less than survival of spruce seedlings in the control (Table 30).

The condition of spruce seedlings in the 5.6 kg/ha rate of Velpar appeared to be worse than the condition of spruce seedlings in the other treatments.

Survival and Condition - Pine

Survival of pine seedlings after all rates of Velpar was good and the majority of seedlings remained in the 0-1 (healthy-good) condition category (Table 30).

Leader Length and Weight - Spruce

The mean leader length and dry weight of spruce seedlings in all Velpar treatments were significantly less than the spruce measurements in the control.

Leader Length and Weight - Pine

There were no significant differences in mean leader lengths or dry weights of pine between treatments (Table 30).

D1c. Simazine, Atrazine and Velpar in a Mixture and Separately at Pass Creek

Herbaceous Vegetation Control

After 3.7 months "poor" (35 to 50%) vegetation control resulted in the plots where simazine and atrazine were applied at 7.8 kg/ha. These herbicides did not control

TABLE 30 Comparisons of Different Dosages of Velpar on Survival, Condition* Leader Length** and Weight*** of White Spruce and Lodgepole Pine Seedlings 11.5 Months after Treatment at Grande Prairie - Experiment Dlb. (Mean of 2 replications).

	Spruce					Pine				
Velpar Dosage kg/ha	% Survival	Condition Category		Leader Length	Dry Weight	% Survival	Condition Category		Leader Length	Dry Weight
		0-1	2-3				0-1	2-3		
0.0	100a****	95	5	100a (4.8cm)	100a (4.8gms)	95a	75	20	100a (4.0cm)	100a (3.0gms)
2.2	85ab	70	15	65b	66b	95a	80	15	100a	118a
3.4	85ab	60	25	63b	57b	85a	65	20	96a	98a
4.5	90ab	70	20	70b	63b	85a	80	10	100a	105a
5.6	80b	40	40	71b	76ab	95a	70	25	100a	95a

* Condition is expressed as a percentage of pine seedlings assigned to each condition category. 0-1: healthy-good and 2-3: fair-poor.

** Leader Length is expressed as a percentage calculated from the mean leader length per conifer seedling per treatment.

*** Dry weight is expressed as a percentage calculated from the mean dry weight per replicate per treatment.

**** Percentages followed by the same letter are not significantly different at the 5% level using Duncan's Multiple Range Test (Duncan, 1955) sedges present in the plots. "Good" (85 to 95%) control was obtained with Velpar at 7.8 kg/ha. Vegetation control with both dosages (7.8 and 15.7 kg/ha) of the herbicide mixture (simazine, atrazine and Velpar) was "good" (75 to 90%). Vegetation control achieved by the herbicide mixture at 7.8 kg/ha, 1.5 months after treatment is illustrated in Plate 7 and the same plot is shown in Plate 8, 3.7 months after treatment.

Scalps without herbicide treatment maintained "fair" (65 to 75%) vegetation control while scalps in plots with herbicide treatment showed "good" (75 to 90%) vegetation control after 3.7 months.

Survival and Condition - Spruce

The percentage survival of spruce seedlings planted in scalp plots without herbicide treatment and in scalps made after spraying was significantly higher than the percentage survival of spruce seedlings in scalps made prior to spraying (Table 31).

Spruce in scalp treatments, excluding spruce in treatments where scalping took place prior to spraying, tended to be in superior condition compared with spruce in all other treatments. The majority of spruce seedlings in the simazine, atrazine, Velpar and the herbicide mixture plots that had no scalping was assigned to the 2-3 (fair-poor) condition category.

Plate 7 Vegetation Control at Pass Creek (Dlc) 1.5 Months After Spring Treatment with a Herbicide Mixture (simazine-2.5 parts, atrazine-2.5 parts and Velpar-2.0 parts) at 7.8 kg/ha. (Plate 8 shows the same plot 3.7 months after treatment).

Plate 8 Vegetation Control at Pass Creek (Dlc) 3.7 Months After Spring Treatments with a Herbicide Mixture (simazine-2.5 parts, atrazine-2.5 parts and Velpar-2.0 parts) at 7.8 kg/ha (Plate 7 shows the same plot 1.5 months after treatment).

TABLE 31 Effects of Herbicides and Scalping on Survival, Condition* and Leader Length** of White Spruce and Lodgepole Pine Seedlings at Pass Creek 3.7 Months After Treatment - Experiment Dlc. (Mean of 3 replications)

		Spruce				Pine			
Treatment	Dosage kg/ha	% Survival	Condition Category 0-1	Condition Category 2-3	Leader Length	% Survival	Condition Category 0-1	Condition Category 2-3	Leader Length
Control		98a***	62	36	100b (2.2cm)	72ab	30	42	100ab (1.1cm)
Scalp		100a	95	5	128a	93a	68	25	132a
Simazine	7.8	97a	37	60	42cd	72ab	21	51	68bc
Atrazine	7.8	88ab	27	61	35c-e	75ab	20	55	62cd
Velpar	7.8	78b	18	60	10e	55b	15	40	29de
Mixture	7.8	80b	36	44	39cd	73ab	22	51	65c
Mixture + Scalp	7.8	100a	82	18	106b	97a	74	23	124a
"	15.7	98a	68	30	86b	92a	70	22	116a
Scalp + Mixture	7.8	80b	42	38	60c	53b	18	35	36c-e
"	15.7	37c	6	31	16be	22c	5	17	15e

* Condition is expressed as a percentage of conifer seedlings assigned to each condition category. 0-1: healthy-good and 2-3: fair-poor.

** Leader Length is expressed as a percentage calculated from the mean Leader length per conifer seedling per treatment.

*** Percentages followed by the same letter are not significantly different at the 5% level using Duncan's Multiple Range Test (Duncan, 1955).

Survival and Condition - Pine

Survival and condition of pine seedlings were similar to what they were for spruce seedlings as noted above.

Leader Length - Spruce

After 3.7 months the mean leader length of spruce seedlings in the scalp plots without herbicide treatment, in the scalps made after spraying and in the controls was significantly greater than the spruce mean in all other treatments (Table 31). The mean leader lengths of spruce seedlings not protected by scalping after spraying ranged from 39 to 90% less than the mean leader length of spruce in the controls. Velpar and the 15.7 kg/ha rate of the herbicide mixture applied over previously made scalps appeared to be the most damaging treatment to spruce seedlings.

Leader Length - Pine

Effects of treatments on the leader length of pine seedlings were similar to those for spruce seedlings.

D1d. Velpar, Fluridone and Simazine - Atrazine-Velpar Mixture at Pass Creek

Herbaceous Vegetation Control

Vegetation control in the Velpar plots with rates of application of 4.5 kg/ha and higher was "good" (80 to 90%) after 4 months. "Fair" (50 to 65%) vegetation control was obtained in plots where the herbicide mixture (simazine-strazine-Velpar) was applied at 4.5 and 6.7 kg/ha and "good"

(80 to 90%) control was obtained in the 9.0 kg/ha dosage of the mixture. Fluridone provided only "fair" to "poor" control (35 to 65%).

Survival and Condition - Spruce

There was no significant difference in percentage survival of spruce seedlings between any treatments, however, the condition of spruce seedlings tended to be better in the scalp treatments compared with the non-scalp treatments (Table 32).

Survival and Condition - Pine

The survival and condition of pine seedlings tended to be similar to that of spruce seedlings with minor exceptions as indicated in Table 32.

Leader Length - Spruce

After 4 months the mean leader length of spruce seedlings in scalps with and without herbicide treatment, was significantly greater than the mean leader length of spruce seedlings in all other treatments, except seedlings in the 4.5 kg/ha rate of fluridone and the control (Table 32).

Leader Length - Pine

After 4 months the mean leader lengths of pine seedlings in the Velpar at 4.5 kg/ha plot and the fluridone at 9.0 kg/ha plot were significantly less than corresponding measurements in all other treatments (Table 32). The leader lengths of pine seedlings in the scalp treatments tended to be longer than the leader lengths in non-scalp treatments however no mean leader lengths of pine in scalp treatment were significantly longer than the mean of the control.

D1e. Velpar, Fluridone and Simazine - Atrazine-Velpar Mixture at Mayberne

Herbaceous Vegetation Control

Vegetation control was similar to that of experiment D1d. (Pass Creek) except that control by fluridone was even less effective at Mayberne.

Survival, Condition and Leader Length - Spruce and Pine

The measurements and observations of pine and spruce at Mayberne support the evidence found at Pass Creek (Table 32) which generally indicates increased survival, condition and leader length of seedlings planted in scalp treatments compared with unscalped treatments.

D2. Tolerance of Conifers to Direct Treatment

D2a. Lodgepole Pine in the Greenhouse

Two months after treatment, fluridone had not reduced survival of pine seedlings but had adversely affected their condition. Survival was reduced by higher rates of Velpar and herbicide mixture (Simazine-Atrazine-Velpar) (Table 33). After 7 months pine survival was reduced in fluridone treatment also.

D2b. White Spruce and Lodgepole Pine at Ellerslie

Herbaceous Vegetation Control

Two months after treatment vegetation control

TABLE 32 Effects of Herbicides and Scalping on Survival, Condition* and Leader Length** of White Spruce and Lodgepole Pine Seedlings at Pass Creek 4 Months After Treatment - Experiment Dld. (mean of 2 replications)

		Spruce				Pine			
Treatment	Dosage kg/ha	% Survival	Condition Category		Leader Length	% Survival	Condition Category		Leader Length
			0-1	2-3			0-1	2-3	
Control		98a***	62	36	100ab (2.4cm)	65a-c	25	40	100ab (1.1cm)
Velpar	4.5	84a	59	25	42c	67a-c	17	50	57b
Fluridone	4.5	100a	50	50	95a-c	67a-c	17	50	103ab
	9.0	92a	8	84	48bc	34c	0	34	44b
Scalp		100a	95	5	131a	95ab	70	25	156a
Velpar + Scalps	4.5	100a	92	8	125a	92ab	75	17	189a
Fluridone + Scalps	4.5	100a	83	17	128a	67a-c	42	25	121ab
"	9.0	100a	50	50	119ab	100a	33	67	180a

* Condition is expressed as a percentage of conifer seedlings assigned to each condition category. 0-1: healthy-good and 2-3: fair-poor.

** Leader Length is expressed as a percentage calculated from the mean leader length per conifer seedling per treatment.

*** Percentages followed by the same letter are not significantly different at the 5% level using Duncan's Multiple Range Test (Duncan, 1955).

TABLE 33 Tolerance (Survival and Condition*) of Lodgepole Pine Seedlings to Direct Herbicide Treatment in the Greenhouse - Experiment D2a.

		2 Months			7 Months		
Herbicide	Dosage kg/ha	% Survival	Condition Category		% Survival	Condition Category	
			0-1	2-3		0-1	2-3
Fluridone	0.0	100	90	10	100	80	20
	3.4	100	20	80	100	90	10
	6.7	90	30	60	70	20	50
	10.0	100	0	100	50	20	30
Velpar	0.0	100	100	0	100	100	0
	3.4	80	70	10	70	50	20
	6.7	90	90	0	90	70	20
	10.0	60	0	60	0	0	0
Mixture	0.0	100	90	10	90	90	0
	5.6	90	80	10	80	60	20
	11.2	60	40	20	40	30	10
	16.8	60	30	30	20	10	10

* Condition is expressed as a percentage of pine seedlings assigned to each condition category. 0-1: healthy-good and 2-3: fair-poor.

in all dosages of the herbicide mixture (simazine-atrazine-Velpar) and Velpar was "good" (80 to 99%). Control was "fair" (50 to 65%) in the 6.7 and 10.0 kg/ha plots of fluridone and "very poor" (10 to 25%) in the 3.4 kg/ha plot.

Survival and Condition - Spruce and Pine

After 2 months, survival and condition of conifers was poor following the higher rates of the herbicide mixture and all dosages of Velpar (Table 34). Survival of pine and spruce in all fluridone plots at this time was equal to controls but there appeared to be deterioration of condition.

TABLE 34 Tolerance (Survival and Condition)* of White Spruce and Lodgepole Pine Seedlings to Direct Herbicide Treatment at Ellerslie - Experiment D2b. (10 plants per treatment)

	Spruce						Pine					
	1 Month			2 Months			1 Month			2 Months		
Herbicide kg/ha	% Survival	Condition Category		% Survival	Condition Category		% Survival	Condition Category		% Survival	Condition Category	
		0-1	2-3		0-1	2-3		0-1	2-3		0-1	2-3
Mixture												
0.0	100	90	10	100	100	0	100	40	60	100	50	50
5.6	100	60	40	60	10	50	80	30	50	70	40	30
11.2	70	10	60	10	0	10	70	40	30	80	10	70
16.8	70	0	70	10	0	10	60	20	40	0	0	0
Fluridone												
0.0	100	90	10	90	70	20	100	100	0	100	50	50
3.4	100	80	20	90	80	10	100	90	0	100	90	10
6.7	100	100	0	100	80	20	100	60	40	100	40	60
10.0	100	100	0	90	80	10	100	80	20	100	60	40
Velpar												
0.0	100	100	0	100	100	0	100	90	10	100	50	50
3.4	100	50	50	50	20	30	70	20	50	10	0	10
6.7	50	10	40	10	10	0	50	10	40	20	0	20
10.0	90	20	70	10	0	10	60	30	30	20	0	20

* Condition is expressed as a percentage of pine seedlings assigned to each condition category. 0-1: healthy-good and 2-3: fair-poor.

III. DISCUSSION AND CONCLUSIONS

A. Effects of Glyphosate Treatment on Control of Weedy Vegetation

Spring applications of glyphosate at 4.5 kg/ha (4 lb/A) provided complete initial control of grasses in all 1976 and 1977 experiments including Mayberne, Stony Plain, Grande Prairie, Pass Creek and Ellerslie (experiments C1a,b, c,d,e and f, C3a and b, C4a,b and c, C5c, C7b and C8a,b,c and d. See Plate 3 - Grande Prairie). Reinvasion occurred more extensively and in a shorter period of time in some experiments than in others. At Stony Plain where vegetation control was poorest, the greatest extent of regrowth seemed to be attributable to greater density of sod together with more diversity of the weed seed population. Since there was almost complete re-establishment of grass cover at Stony Plain in experiments C1b and e and C8a (Plate 2) before the fall of the year following treatment and approximately 35% re-establishment at other sites (Plate 1 Mayberne) the potential adequacy of a single spring application of glyphosate for benefit to conifer implants became questionable. Later season applications of glyphosate in dosages ranging from 1.1 to 5.6 kg/ha (1 to 5 lb/A) in experiments C2a and b and C5a,b and d provided much more effective retardation of weedy regrowth. In those experiments the 1.1 kg/ha rate was nearly as effective as the 5.6 kg/ha rate (Plate 5 Mayberne). Improved control by late summer spray treatments may be at least partly owing to the presence of more foliage of the weedy species later in the year.

The 1.2 m strips treated in spring with 4.5 kg/ha of glyphosate appeared to have superior protection from vegetation reinvasion compared with the 28 and 56 cm spots treated with the same dosage of glyphosate (experiments Cla,b,c,d,e and f - Table 9). On the basis of this evidence, presented in Table 9, and because of the ease of strip application compared with treatment of individual spots, it seems advisable to use strip treatments in future small or large scale trials involving pre-planting treatments.

Late summer or fall glyphosate treatments at dosages as low as 2.2 kg/ha offer the possibility of being able to begin planting conifer seedlings early in the following spring without having to wait for grass foliage to be ready for spraying. Sprayed strip areas would be easily visible during the growing season following spraying, thus facilitating their location for placement of seedlings in competition-free areas. However, as with the spring treatments of glyphosate, the adequacy of a single treatment for sufficiently long lasting grass control is somewhat doubtful. This point is supported in the next section, showing that beneficial effects to conifer survival and growth were not evident up to 14 months after either late summer or spring glyphosate treatments.

B. Effects of Glyphosate Treatments on White Spruce and Lodgepole Pine Seedlings

Strip and spot treatments with glyphosate at

4.5 kg/ha applied one day prior to planting, appeared to have neither a beneficial nor a detrimental effect on spruce seedlings at Mayberne (C1a) and Grande Prairie (C1c). Within the two years of experiments at Stony Plain (C1b), however, spruce seedlings after glyphosate treatments fared less well than spruce seedlings in untreated areas.

In contrast with spruce, pine seedlings planted within one day or immediately after spraying with 1.1 to 5.6 kg/ha of glyphosate, were seriously damaged in relevant 1976 and 1977 field experiments at Stony Plain, Grande Prairie, Mayberne and Pass Creek (C1e and f, C2a and b, C4a and c and C5c) with the exception of the 1976 spring treatment at Mayberne (C1d), in which no significant damage occurred. Likewise, direct, over-the-top spraying of recently planted seedlings injured them (C7b).

Injury to pine seedlings as a result of preplanting glyphosate treatment was not anticipated on the basis of the manufacturer's technical information,

> "There is no apparent soil residual activity or preemergence effect when ROUNDUP (glyphosate) is sprayed onto soil or if it contacts soil indirectly through decomposing vegetation". (Monsanto 1973)

In the present work the fact that planting followed soon after spraying and without the customary post-spraying cultivation performed in work with farm crops, appears to be a major factor responsible for the injury observed with the conifer implants.

Damage to pine was most severe in experiments C1e, C2b, C4a and C5c at the Stony Plain site. The soils at this location are coarse textured and well drained, therefore the ability for immediate adsorptive retention of the herbicide may be poor.

In experiment C4b (Stony Plain), in which spraying with glyphosate at 4.5 kg/ha preceded planting by 6 days, pine seedlings were not damaged. Similarily, in experiment C5a (Mayberne) and C5b (Stony Plain) where spraying preceded planting by 10 months, no damage occurred. Therefore, delayed planting is one possible solution to the problem of pine damage by glyphosate.

In the 3 experiments discussed in the preceding paragraph (C4b and C5a and b), in which glyphosate treatment and delayed planting did not cause unacceptable injury to the pine seedlings, there was no apparent beneficial effect on growth of pine within the short period of time before final observation in 1977, 3 months after planting. However the effect of the shock ("check") suffered in the first growing season by transplanting the seedlings may have nullified any potential benefit of the reduced vegetative competition. Increased growth and vigor of pine planted following enough delay after glyphosate treatment, might occur in the year following treatment, provided reinvasion of grasses and forbs is not complete early in the season. The available results for such experiments involving glyphosate (Cla and d - Mayberne and Clc and f - Grande Prairie) showed that total vegetation reinvasion had not occurred by the end of the second growing season, therefore conifer seedlings not planted too soon after the herbicide treatment may benefit in the second year.

It was suspected that glyphosate damage to newly planted pine seedlings was the result of movement of glyphosate over short distances with the soil solution. The physical transfer of glyphosate from the leaves of treated grass to the leaves of pine was also suspected. However, the latter possible source of glyphosate injury appears least likely since observations indicated that many of the dead pine, particularly at Mayberne, had no opportunity for their leaves to receive drips from or to contact the leaves of surrounding treated grasses.

In experiment C6e in the greenhouse, damage occurred to pine seedlings in contact with grass leaves treated with 8.9 kg/ha of glyphosate. It is possible that glyphosate could have entered the pine seedlings by the leaves and roots. Lack of damage to pine seedlings in greenhouse experiment C6d where treated grass leaves were suspended over the seedlings and subjected to repeated washing seems to suggest the requirement for physical contact between treated grass and pine leaves to induce injury to the pine. The effect of sprinkling the treated grass may have diluted the glyphosate solution to the point of being ineffective in causing damage through the soil in this experiment (C6d).

The damage to pine seedlings in the field after spring planting was least at Mayberne (C1d), distinct from other similar experiments in which considerable damage occurred. In addition in experiment C6c in the greenhouse, pine planted in pots containing sprayed, bare Mayberne soil suffered little damage compared with the other soils. A possible explanation for this difference appears to be soil pH. Anderson (1977) indicates that "Herbicides are adsorbed more strongly in soils which are acid and less so in those which are alkaline". The soil at Mayberne was acidic with a pH of 4.9 (Table 1). The pHs at Stony Plain, Grande Prairie and Pass Creek were 6.7, 8.2 and 5.5 (Tables 2, 3 and 4), respectively. On the other hand damage to pine was severe at Pass Creek (C4c), in soil which had a relatively low pH of 5.5. However the glyphosate spraying of the dense grass at this location preceded planting by only 3 hours. Perhaps this allowed insufficient time for soil adsorption of free glyphosate compared with Mayberne where planting was done on the day after spraying. However, it is difficult to rest an explanation confidently on the pH factor in view of the fact that there was significant damage to pine planted the day after the late summer glyphosate treatment at Mayberne in 1976 (C2a). This injury occurred from the same pre-planting dosage that caused no significant injury to pine following planting at Mayberne in the previous spring (C1d).

Greenhouse and growth chamber experiments using pre-germinated pine seeds (C6a) also demonstrated the damaging effect of glyphosate on seedling survival and growth.

Seedlings from seeds that were not pre-germinated were not injured (C6b). Since the pre-germinated pine (C6a) was actively growing when placed in the soil, which was sprayed one day later, it appears that glyphosate was not immediately adsorbed by soil colloids but was able to move in the soil solution enough to contact the actively growing newly germinated pine seedlings.

It seems likely that no damage occurred in experiment C6b, commenced with ungerminated seed, because there was sufficient time for glyphosate to become adsorbed by the soil before the seeds became sensitive.

This evidence obtained in the greenhouse tends to support results of experiment C4b where planting of pine seedlings delayed for 6 days after spraying resulted in no damage to the seedlings. The short delay appeared to provide the time required to inactivate glyphosate. Since severe damage resulted to pine seedlings planted in 4 of the soil types, one day after glyphosate spraying of bare soil in the greenhouse (C6c), the obvious explanation appears to be that glyphosate entered the pine seedlings via the root system from the soil solution.

The preliminary experiments (C7a and b) carried out in the greenhouse and field to observe the effects of direct "over-the-top" treatments, suggest unacceptable loss of spruce and pine seedlings at glyphosate dosages of 4.5 kg/ha and above. Further experimentation with rates of application of glyphosate lower than 4.5 kg/ha, sprayed "over-the-top" of established conifer seedlings, should be carried out. Results from experiments C5a,b,c and d indicate that acceptable grass control in the first year can be obtained with glyphosate dosages as low as 1.1 and 2.2 kg/ ha particularly at later stages of grass growth. When spraying is delayed, the grass cover present later in the growing season can be expected to provide some protection of already established conifers from direct spraying. Evidence from experiment C5d at Economy suggested that 4 year old pine were free from visible damage for up to 1 year after direct spraying. Established seedlings not suffering from "planting shock" may be more tolerant to glyphosate particularly in instances where low dosages of this herbicide might be adequate. However, in the tests at the Economy site there was no clear evidence that tree growth after treatment had been improved in comparison with similar pines in adjacent unsprayed areas and it is also questionable whether trees already established for this length of time could benefit significantly from removal of grass competition.

C. Effects of Scalping and Fertilization on White Spruce and Lodgepole Pine

Scalping appeared to provide beneficial effects to spruce and pine seedlings in experiments at Mayberne, Stony Plain and Grande Prairie (C1a,b,d,e and f and C2b). These experiments provide an indication that the removal of organic matter to facilitate planting of conifer seedlings into mineral soil can be a valuable practical management tool, for increases in seedling condition, height and weight. Experiments Cla,b,c,d,e and f (Tables 10, 11, 12 and 13) indicated that the greatest growth increases occurred during the second growing season after establishment.

Fourteen months after treatment at Mayberne (Cla) and Stony Plain (Clb) spruce in unfertilized scalps averaged 20% more height growth than spruce in the control and at Stony Plain (Cle) and Grande Prairie (Clf) pine in similar scalps averaged a weight increase of 46% compared with the control. Fertilization of spruce and pine seedlings also resulted in beneficial effects (Cla,b,c,d,e and f). The response of spruce seedlings during the first growing season was not pronounced, however, after the second growing season favorable growth and weight increases were observed in the fertilized control and fertilized scalp compared with their nonfertilized counterparts.

In contrast to spruce seedlings, pine achieved greater height and weight increases during both the first and second growing seasons after treatment. However, these increases occurred only in the scalp treatments. Fertilized spruce or pine in glyphosate treatments generally did not increase in height or weight compared to their non-fertilized counterparts. The evidence therefore indicates that the best growth of spruce and pine seedlings after two growing seasons occurred in the fertilized, scalp treatments.

At the end of the second growing season after treatment at Mayberne (Cla and d), Stony Plain (Clb and e) and Grande Prairie (Clc and f) spruce and pine in fertilized scalps averaged a 30% increase in height over spruce and pine in the unfertilized controls. In addition, after the same time period at Stony Plain (Clb and e) and Grande Prairie (Clc and f) spruce and pine in fertilized scalps increased in weight by 70 and 100% respectively, compared with the unfertilized controls.

On the basis of the foregoing results it would appear that fertilization and scalping as performed in this project is worth favorable consideration as a commercial management tool to increase productivity. Scalping or scarification is a common practice in reforestation projects in Alberta at the present time but, fertilization is not. Fertilization and scalping together provided maximum benefits to spruce and pine seedlings in this project. Consequently it is recommended that, if economically feasible and if further large scale experiments support the evidence presented here, these combined practices should become a part of reforestation programs in Alberta.

D. Effects of Glyphosate on Willow and Caragana

Experiments C8a and b at Stony Plain and Grande Prairie provided positive evidence of a weight increase of willow in glyphosate treatments in 1.2 m wide strips. The scalp treatments increased the weight of willow significantly at Stony Plain (C8a), but similar results were not obtained at Grande Prairie (C8b) therefore further research with scalp treatments would be necessary to settle this aspect.

A clear trend for increase in caragana growth as a result of removal of grass competition was not evident from experiments C8c and d, possibly as a result of the short duration of these experiments. Further research is suggested.

E. Effects of Soil Treatments and Scalping on Competing Vegetation and on White Spruce and Lodgepole Pine

Most soil active herbicides used in this project provided acceptable levels of vegetation control. However, the evidence indicates that planting of spruce and pine seedlings directly into plots treated one day before planting is unfeasible.

Vegetation control by karbutilate at Mayberne in both dosages (7.8 and 15.8 kg/ha) 14 months after treatment was good (Dla). Velpar at Mayberne and Pass Creek at dosages of 4.5 kg/ha or more, also provided good control 3 months after treatment (Dlc,d and e). However, unacceptable damage occurred to the conifer seedlings from both herbicides in non-scalp treatments.

Velpar, applied 9 months before planting at rates from 2.2 to 5.6 kg/ha, appeared not to affect the pine at Grande Prairie (Dlb). These seedlings were planted into a layer of organic matter which may have provided protection from Velpar. Anderson (1977) indicates that herbicides "are more strongly adsorbed to particles of humus than those of clay", therefore Velpar may have become partly deactivated by the organic layer. Spruce seedlings were less tolerant of Velpar than pine seedlings in this trial (Dlb).

Vegetation control after 3 months was fair to poor in simazine (Dla and c), atrazine (Dlc) and fluridone (Dld and e) plots while all rates of the herbicide mixture (SAV - simazine-2.5: atrazine-2.5: Velpar-2) (Dlc,d and e) provided good vegetation control within the same time period. The most effective vegetation control was achieved by Velpar and the herbicide mixture. The duration of these experiments has not yet been long enough to determine which treatment will provide longest lasting control.

The extent of survival of pine and spruce planted directly into unscalped simazine, atrazine, fluridone and the herbicide mixture plots was generally acceptable, however, the leader length measurement indicated the growth was considerably less in these treatments compared with the controls.

Conifer seedlings planted into scalps without herbicide treatment and into scalps with the SAV herbicide mixture applied immediately prior to scalping, had growth superior to their respective controls (Dlc,d,e). It is, of course, too soon to be able to decide whether the conifer seedlings will remain healthy after being planted in scalps surrounded by the SAV treatments. So far, however, this technique seems promising and merits attention concerning its potential for better establishment and growth of seedlings in scalps that may be protected from perennial grass re-invasion by a surrounding herbicide treatment. Such a mixture with components of differential solubility, depth of penetration, toxicity and persistence may be better able than a single herbicide to provide fairly quick, selective and reasonably long lasting control. Ideally the control and subsequent herbicide degradation would occur without movement of herbicide into the root zone of the conifer implants in sufficient quantity to injure them. A successful soil treatment procedure of this nature involving granular applications would be easy to use and would facilitate planting schedules. It would avoid the need to wait within a growing season for suitable foliage development needed for foliar sprays and would not require dependence on there being suitable calm spraying weather as well as absence of rain immediately after the operation.

APPENDIX I

Partial List of Prevalent Plant Species Present at Field Sites

A. Mayberne

Abies balsamea (L.) Mill.	(Balsam Fir)
Agrostis scabra Willd.	(Tickle Grass)
Alnus crispa (Ait.) Pursh	(Green Alder)
Aralia nudicaulis L.	(Wild Sarsaparilla)
Bromus inermis Leyss.	(Common Brome Grass)
Calamagrostis canadensis (Michx.) Beauv.	(Marsh Reed Grass)
Castilleja sp.	(Indian Paint-brush)
Cornus canadensis L.	(Bunchberry)
Corydalis aurea Willd.	(Golden Corydalis)
Epilobium angustifolium L.	(Fireweed)
Fragaria sp.	(Strawberry)
Galium triflorum Michx.	(Sweet-scented Bedstraw)
Gentianella amarella (L.) Borner	(Felwort)
Geranium bicknellii Britt.	(Bicknell's Geranium)
Heracleum lanatum Michx.	(Cow Parsnip)
Linnaea borealis L.	(Twin-flower)
Lonicera involucrata (Richards) Banks	(Bracted Honeysuckle)
Luzula glabrata (Hoppe) Desv.	
Mertensia paniculata (Ait.) G. Don	(Tall Mertensia)
Mitella nuda L.	(Bishop's-cap)
Petasites frigidus (L.) Fries	(Sweet Coltsfoot)
Phleum pratense L.	(Timothy)
Picea glauca (Moench) Voss	(White Spruce)
Pinus contorta Loudon var. *latifolia* Engelm.	(Lodgepole Pine)
Populus tremuloides Michx.	(Aspen)
Ribes sp.	
Rosa sp.	(Wild Rose)
Rubus sp.	(Raspberry)
Salix sp.	(Willow)
Smilacina stellata (L.) Desf.	(Star-flowered Solomon's-seal)
Solidago sp.	(Goldenrod)
Sorbus scopulina Greene	(Mountain Ash)
Vaccinium caespitosum Michx.	(Dwarf Bilberry)
Viola sp.	(Violet)

B. Stony Plain

Achillea millefolium L.	(Common Yarrow)
Agropyron dasystachyum (Hook.) Scribn.	(Northern Wheat Grass)

A. *repens* (L.) Beauv.	(Quack Grass)
Androsace septentrionalis L.	(Fairy Candelabra)
Campanula rotundifolia L.	(Harebell)
Capsella bursa-pastoris (L.) Medic.	(Shepherd's-purse)
Chenopodium album L.	(Lamb's-quarters)
Cirsium arvense (L.) Scop.	(Canada Thistle)
Collomia linearis Nutt.	(Collomia)
Crepis tectorum L.	(Narrow-leaved Hawk's beard)
Equisetum arvense L.	(Field Horsetail)
Erigeron sp.	(Fleabane)
Festuca rubra L.	(Red Fescue)
Lathyrus ochroleucus Hook.	(Pea Vine)
Monolepis nuttalliana (Schultes) Breene	(Spear-leaved Goosefoot)
Neslia paniculata (L.) Desv.	(Ball Mustard)
Poa pratensis L.	(Kentucky Bluegrass)
Sisyrinchium sp.	(Blue-eyed Grass)
Sonchus arvensis L.	(Perennial Sow Thistle)
Symphoricarpos occidentalis Hook.	(Buckbrush)
Taraxacum officinale Weber	(Common Dandelion)
Thlaspi arvense L.	(Stinkweed)
Trifolium hybridum L.	(Alsike Clover)
Vicia americana Muhl.	(Wild vetch)

C. Grande Prairie

Agropyron cristatum (L.) Gaertn.	(Crested Wheat Grass)
Apocynum androsaemifolium L.	(Spreading Dogbane)
Aster sp.	(Aster)
Calamagrostis canadensis (Michx.) Beauv.	(Marsh Reed Grass)
Chenopodium album L.	(Lamb's-quarters)
Crepis tectorum L.	(Narrow-leaved Hawk's-beard)
Epilobium angustifolium L.	(Fireweed)
Erigeron canadensis L.	(Horseweed)
Festuca rubra L.	(Red Fescue)
Galium boreale L.	(Northern Bedstraw)
G. *Triflorum* Michx.	(Sweet-scented Bedstraw)
Lappula echinata Gilib.	(Bluebur)
Lathyrus ochroleucus Hook.	(Pea Vine)
Melilotus officinalis (L.) Lam.	(Yellow Sweet Clover)
Phleum pratense L.	(Timothy)
Populus balsamifera L.	(Balsam Poplar)
P. *Tremuloides* Michx.	(Aspen)
Rosa sp.	(Wild Rose)
Rubus sp.	(Raspberry)
Solidago sp.	(Goldenrod)
Symphoricarpos occidentalis Hook.	(Buckbrush)
Taraxacum officinale Weber	(Common Dandelion)
Thlaspi arvense L.	(Stinkweed)
Trifolium hybridum L.	(Alsike Clover)

T. pratense L.	(Red Clover)
Vicia americana Muhl.	(Wild vetch)
Viola sp.	(Violet)

D. Pass Creek

Achillea millefolium L.	(Common Yarrow)
Agropyron trachycaulum (Link) Malte	(Slender Wheat Grass)
Betula papyrifera Marsh.	(Paper Birch)
Bromus ciliatus L.	(Fringed Brome)
Calamagrostis canadensis (Michx.) Beauv.	(Marsh Reed Grass)
Carex sp.	
Cerastium sp.	(Chickweed)
Delphinium glaucum S. Wats.	(Tall Larkspur)
Epilobium angustifolium L.	(Fireweed)
Galium boreale L.	(Northern Bedstraw)
Geum sp.	(Avens)
Heracleum lanatum Michx.	(Cow Parsnip)
Lathyrus ochroleucus Hook.	(Pea Vine)
Lonicera involucrata (Richards.) Banks	(Bracted Honeysuckle)
Mertensia paniculata (Ait.) G. Don	(Tall Mertensia)
Picea glauca (Moench.) Voss	(White Spruce)
Populus tremuloides Michx.	(Aspen)
Potentilla norvegica L.	(Rough Cinquefoil)
Ribes sp.	
Rubus sp.	(Raspberry)
Schizachne purpurascens (Torr.) Swallen	(False Melic)
Taraxacum officinale Weber	(Common Dandelion)
Thalictrum sp.	(Meadow Rue)
Urtica gracilis Ait.	(Nettle)
Vicia americana Muhl.	(Wild Vetch)

E. Economy

Arabis drummondii A. Gray	
A. glabra (L.) Bernh	(Tower Mustard)
Beckmannia syzigachne (Szeud.) Fern.	(Slough Grass)
Calamagrostis canadensis (Michx.) Beauv.	(Marsh Reed Grass)
Carex sp.	
Cinna latifolia (Trev.) Griseb.	(Drooping Wood Reed)
Glyceria grandis S. Wats.	
Poa palustris L.	(Fowl Bluegrass)

APPENDIX II

Interpretation of Soil Test Results

A. Range of Available Plant Nutrients in kgs per 1 million kgs of soil

Rating	Nitrogen (N)	Phosphorus (P)	Potassium (K)
Low	0 - 10	0 - 15	0 - 75
Medium	11 - 25	16 - 35	76 -150
High	26 or more	36 or more	151 or more

B. Soil Reaction (pH)

pH Values

	5.0		5.5		6.0		6.5		7.0		7.5		8.0		8.5	
very strongly acid		strongly acid		medium acid		slightly acid		neutral		neutral		mildly alkaline		moderately alkaline		strongly alkaline

↑Best range for most crops↑

C. Conductivity and Soil Salinity

Conductivity Test	
0 - 2	negligible salt effects
3 - 4	very sensitive crops affected
5 - 10	yield of most crops reduced
11 - 16	only tolerant crops satisfactory
16+	very high

APPENDIX III

List of Herbicides

Common Name	Manufacturer	Chemical Name	Solubility in Water at 25°C (PPM)
Atrazine	Ciba-Geigy	2-chloro-4-(ethylamino)-6-(isopropylamino)-S-triazine	33
Fluridone	Elanco	1-methyl-3-phenyl-5-[3-(trifluoromethyl) phenyl] -4(1H)-pyridinone	12
Glyphosate	Monsanto	N-(phosphonomethyl) glycine	1200
Simazine	Ciba-Geigy	2-chloro-4,6-bis (ethylamino)-S-triazine	5
Velpar	Dupont	3-cyclohexyl-6-(dimethylamino)-1-methyl-1,3,5-triazine-2,4(1H,3H)-dione	32000

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